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THE
PLANT WORLD

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**An Illustrated Monthly Magazine
of General Botany**

Edited by
FORREST SHREVE

Published by
THE PLANT WORLD ASSOCIATION

Volume 14

122613
18/6/12

Tucson, Arizona
1911

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Volume 14 Number 1

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

JANUARY, 1911

THE BEHAVIOR OF TANNIN IN PERSIMMONS, WITH SOME NOTES ON RIPENING. *

FRANCIS E. LLOYD.

Perhaps no phenomenon of ripening is so obviously remarkable as the apparent disappearance of tannin during this period. Within a few days, or even a few hours, uneatable astringent fruits,—of which the persimmon is a proverbially familiar example,—become fit for the palate. Another example, which has been studied chiefly by Vinson (1907, 1910) and by myself (1910), is the date. This fruit contains a notable quantity of tannin laid down chieflly in a definite zone at the outer limits of the mesocarp. The position of this tannin makes it possible to render it tasteles in a short period by treatment with the fumes of vinegar, a method practiced by the Arabs; and Vinson has found that the same result may be had by means of numerous substances. The persimmon is also ripened artificially by the Japanese (Fairchild, 1905) so far in advance of the natural course of events that, in place of a soft, mushy, or watery fruit, one of the consistency of an apple is obtained, which is similarly peeled and eaten. A fully developed, well-colored, but still hard and unripe fruit, has, indeed, a fragrance suggestive of the apple, and one can easily imagine the fruit in this condition without the astringency ,to be quite desirable. While probably not the only change which ensues under the Japanese method of treatment, the elimination of the tannin is the *sine qua non* of the process.

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*This work should be considered a continuation of that on the date begun at the Arizona Experiment Station, as part of an Adams Fund project, and continued at the Agricultural Experiment Station of the Alabama Polytechnic Institute.

That this takes place is the fact; the explanation of it has been the subject of some inquiry, but with little enlightenment, at least with respect to the two fruits above named. The problem divides itself naturally and trenchantly into two parts; one dealing with fruits from which, during ripening, the tannin disappears by chemical change, as oxidation; and that dealing with cases in which the tannin becomes "insoluble" but apparently unaltered chemically. The date and persimmon are of the latter kind. But wherein does this insolubility consist? To this question no adequate answer has been given. That it unites with some other substance ,as "marc," has appeared possible, but no evidence is forthcoming that this is the case. (Bigelow, Gore, and Howard, 1906). That the change does not involve a metastasis of the tannin molecule (Vinson, 1910) can hardly be denied, nor that some change has intervened to alter the physical potentialities of the substance. It is, indeed, just this latter circumstance which baffles the student, since physical tests no longer apply, *e. g.*, astringent tannin becomes non-astringent.

The purpose of the present paper is to re-open the problem in the light of a study of the persimmon during ripening. The account which follows will be found to disagree at some points with those of other observers, and at others to supplement them. The work, which is by no means yet complete, has been intended to supplement that done on the date (Lloyd, 1910). Since fresh material of ripening stages was not available, the conclusions reached were of necessity inadequate. It is expected that the coming season will afford the opportunity of further study of this form.

HISTOLOGY OF THE PERSIMMON FRUIT.

The pericarp is readily divided into the usual three regions, ecto-, meso-, and endocarp. The thickness of each varies in our native and exotic species, but these differences are of minor moment in the present connection. Evident physiological differences, which will be referred to beyond, are displayed during ripening.

Ectocarp. The ectocarp consists of a heavy cuticularized epidermis of tanniferous cells, the guard cells offering no exception. Four to six layers of more or less compressed frequently tanniferous parenchyma cells intervene until a zone of stone cells is reached. This may be regarded, for convenience, as the inner-most ectocarp layer. The cells are irregular in shape, and are characterized by very numerous slender pores. Aside from this detail, the ectocarp in the persimmon simulates that in the date very closely. In the persimmon it scarcely exceeds 0.2 mm. in thickness.

Mesocarp. Aside from the vascular tissue, this portion of the fruit is composed of two kinds of cells, ordinary parenchyma and tannin cells, or idioplasts. There appears to be no ground for regarding these cells as physiologically identical at first with the non-tanniferous parenchyma or pulp-cells, as I shall call them hereafter. Although they may be difficult to distinguish optically, at an early stage, just as the *Anlagen* of different organs, they are as definitely specialized cells as raphide idioplasts are. I emphasize this point, since the position has been taken that, during ripening, there occurs within certain cells a segregation or condensation of tannin previously distributed throughout the parenchyma (Howard, 1906). I have examined fruits during the whole period of development, using copper acetate, and Vinson's method of fixation by means of ethyl nitrite, and at all times the tannin cells are clearly distinct from the pulp cells, while these are entirely devoid of tannin. If, however, sections are cut for microscopic examination from fresh, unfixed material the dislocation of tannin renders it impossible to arrive at this conclusion, unless great care is exercised. The rupturing of the tannin cells results in the spreading of the tannin fluid so as to confuse observation when a tannin-testing agent is applied. In order to get a clear conception of the distribution of tannin in the unripe fruit the tissues must be fixed suitably *before sections are cut.*

The shape of the tannin cells differs to some degree in the various species. Howard has stated the pertinent facts clearly, and has published excellent photographs (1906). It should be said that although the distinctions apply in a broad way, the tannin cells near the vascular tracts are long and slender in all species. The distribution of these cells in the mesocarp is well shown by Vinson's photograph, published in the *Botanical Gazette* (49: 222).

Endocarp. This region may be recognized as a trans-lucent zone entirely free from tannin cells, except that the epidermal cells of the membrane lining the locule frequently contain tannin. The cells, other than these, are identical, to all appearances, with the pulp cells, are regularly but only slightly elongated, and are placed with their longer axes directed toward the locule. The endocarp is peculiar in not becoming mushy or in any degree deliquescent in the Japanese variety during ripening In our own species sufficient disintegration takes place so that only a thin membrane of gelatinous consistence remains, usually enwrapping the seed. This resistance by the endocarp to a change which overtakes the mesocarp, from which the former is not sharply separated, is remarkable. The mesocarp becomes quite watery during ripening, in contrast to a mushy-granular condition in the American. This is due to the breaking down of the middle lamella (Howard) resulting in the formation of substances which act plasmolytically upon the cells, which, in a ripe fruit, are collapsed, with their plasmatic membranes shrunken well toward the center of the cell. This is true of both pulp and tannin cells, but the latter do not show the effect so evidently since the vacuole is occupied by tannin, or rather a tannin-containing mass which may perhaps be identified with Af Klerker's "tannin-vesicle." The fact that the tannin-cells as such are plasmolysed in the ripe fruit is of importance in view of their behavior upon treatment with water or saliva, to which reference will be made. We may now focus attention upon the mesocarp cells, as at the present moment we are especially concerned with these.

The cells of the mesocarp. The pulp cells are very thin walled, and before ripening are firmly bound together. No sign of plasmolysis appears. The very thin plasmatic membrane, the nucleus suspended near the center of the cell, and the radiating threads of protoplasm are all normal and in position. Spindle shaped coloring bodies (carotin) are distributed through the protoplasm.

The tannin cells have thicker walls with groups of wide pores on the facets opposed to contiguous pulp cells. These are brought out clearly by means of iodine, to which the wall reacts blue. Adjacent tannin cells are attached to each other by means of bridges (Howard) between which are intercellular spaces. The importance of these spaces in relation to possible physiological phenomena within the tannin cells would seem to be unquestionable, but we have no precise light on the matter.

The plasmatic membrane, which contains carotin bodies, is thin except in restricted areas, and the nucleus is lateral in position. The vacuole is occupied, in the ripe fruit, by a tannin-mass (or two or more) suspended in the sap. The protoplasm does not lie immediately against it at all points (figs. 2, 8). The origin and behavior of this tannin mass calls for special discussion.

The tannin-mass. I use this somewhat clumsy term to avoid, in a degree, the idea that the tannin content of the cells in question is a watery solution, or that it is merely tannin. I hold that neither of these conceptions is correct, but I do not venture to assert that the proof of them is complete.

The working theory which is here adopted is that the tannin is associated with a mucilaginous or gelatinous substance which acts as a carrier, and that its insolubility in the ripe fruit is due to its chemical union with this carrier, in the fashion that tannin unites with gelatine, glue, *et cetera, in vitro.* This explanation may not be new, but I do not find that any studies have been made to throw light especially on this point.* Howard, it is true, has given us some information, and has used expressions which show that the presence of a mucilage or mucilage-like material may have been suspected by him. The possibility, however, that the tannin is united with some "undetermined solid" is set aside for the view that the "tannin itself becomes insoluble within certain specialized cells." It will be seen that my view, as above stated, is at variance with that of Bigelow, Gore, and Howard, as stated in their joint paper of 1906. In taking this issue, I do not claim full conviction, except as to the point that the tannin *as such* becomes insoluble. The explanation itself requires to be explained, since such a change, unaccompanied by any other, chemical or physico-chemical, appears to be highly improbable. At the start, however, we must note that inquiry into the matter is balked by the difficulty of applying suitable tests to the tannin masses. Tannin tests give the same color results whether the tannin is free or combined with a colloid. I have examined for comparison with the tannin masses, tannin-gelatine, tannin agar, and tannin albumen. The result obtained is that these substances, particularly the tannin gelatine and albumen, behave in almost all respects like the tannin-masses in the ripe persimmon. There is a slight quantative difference in that the tannin reaction with iron chloride fades away into the usual dirty brown more readily in tannin-gelatine In the tannin masses the browning follows on boiling, and then occurs superficially. This, however, could be explained on the ground that the carrier in the tannin-cells is not a gelatin. As regards the physical appearance and its behavior toward dehydrating agents, and conversely,the tannin-gelatine simulates the tannin-masses so completely as well-nigh to deceive the observer. The recovery of form on release of pressure under the cover-glass, and the fragmentation, seen by Howard in the tannin masses, are very similar. The progressive friableness in the latter is relative to the amount of dehydration, and denotes, probably, nothing else. After a certain degree of solidity has been reached so that the tannin-masses remain intact when observed in water, further change may be obviated at any point simply by isolating the tannin cells by shaking and decantation. I have kept them three weeks or longer and no change was observable, in distilled and tap water. On the other hand the changes in question take place during digestion with pepsin *in vitro* or in the digestive tract, independently of the fruit .(figs 9, 10).

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*Because I have not yet seen f Klerker's paper in the original form, I fear that I may do him scant justice

If, on the other hand, we examine the contents of the tannin cells previous to the point at which the tannin-masses are able to maintain their integrity, the cells, when placed in water or saliva, will burst, and, as Howard has properly put it, the contents "mingle" with the surrounding fluid. But we have to note that although they mingle, the resulting mixture is of the same nature as a thin, well-cooked starch-water mixture. This can be shown by the addition of iodine, which at once coagulates the cell-contents, and one then observes them as stringy masses throughout the water. The negative results obtained on treating with iodine a strong solution of tannin (commercial) imprisoned by cotton fibers, seems to indicate that the fluid which escapes from the cells is not a simple tannin solution in water but that it is a loosely combined tannin-substance analogous to tannin-gelatin. A granular appearance which is visible after coagulation with iodine supports this conclusion, since iodine fails to produce the same granulation with tannin.

If a small piece of the pulp of a hard, unripe fruit be mounted in strong sugar solution and crushed to expel the contents of the cells, the "tannin" and protoplasm will be seen to mingle with the sorrounding fluid. A preparation of this kind which stood for sixteen hours showed, upon the addition of ferric chlorid, that the "tannin" was still to be seen as sheets and strings, accompanied with protoplasm. The protoplasm, cell walls *and* tannin-masses all showed a blue reaction, and the last were coagulated. It seems therefore that the tannin in the unripe fruit is partly separable from the mobile semi-fluid which holds it in the cell,and that in this situation it is not a water-tannin solution. The initial blue coloration in the coagulum fades away into dirty brown, the change noted in tannin-gelatin.

A droplet of water-egg-albumen mixture was heated to coagulation on a slide, treated with tannin, washed off thoroughly and stained with ferric chlorid. A little unripe fruit juice got by scraping the hard pulp was similarly treated, except that the exposure to tannin was omitted. The resulting coagula were so similar that the only difference observable was that the albumen-tannin appeared to hold the blue color longer than tannin-gelatin.

In these experiments the similarity of artificial tannin compounds used and the tannin-mass is highly suggestive, and the conclusion is hard to resist that the tannin-mass is a compound, and not a solution in mere cell-sap.

I have, however, sought for more direct evidence by attempts to separate the tannin from the supposed carrier, and with a measure of success. By means of treatment with dilute nitric acid, the whole mass was completely dissolved in most of the cells,leaving only the partly hydrolysed wall and some granular matter. In some of them, however, there remained a yellow hyaline or very slightly granular shell, which gave no tannin reaction(figs. 12,13). The wall of this shell was about three microns thick. To account for this substance aside from its origin in the tannin-mass, is difficult. Its physical characters are like those of the tannin-mass before extreme hardening. This matter needs further study, but as it stands it gives rather strong support to my main contention.

The progressive dehydration above mentioned appears to Howard to be connected with the fixation or rendering insoluble of the tannin. I base this statement on the explanation given by him as to why an astringent after taste is had on eating slightly under-ripe fruits which * * * "first produce a fine sweet taste, while it takes about half a minute for the taste to detect any astringency; this of course being due to the fact that the saliva, being a liquid of low osmotic strength, causes in a few seconds a swelling and rupturing of the tannin-cells and finally the development of astringency." The condition referred to is illustrated in his sixth figure, p. 573, (1906). The formation of a whitish, granular substance on contact of the "expelled cells contents" with water is noted, and this, it appears to be inferred, is due to the solution or disorganization of the tannin-mass, although this is not stated exactly.

In my own experiments I have found that the swelling of the tannin-mass even to the extent illustrated in the figure above quoted is not necessarily accompanied by a soluble condition of the tannin. I have repeatedly isolated large quantities of tannin cells from fruits which have been over-ripe for a week or even longer and were so soft and watery that the alcohol-insoluble pectose * ran freely into a test-tube. Practically every cell burst, and the tannin-mass extruded. Long standing in water and in alcohol failed to show the extraction of even a trace of its tannin, which, it should be added, could not be tasted in the slightest degree. Furthermore, I have observed the same behavior in a few cells from a portion of fruit which had been exposed to ethyl nitrite for several days, though most of them had passed into a condition of dehydration from which they could not be recalled to an extent sufficient to burst the confines of the cell wall. (fig. 6).

The swelling and extrusion in any event are together but a stage in the progress of dehydration. Still later on the tannin-mass will swell sufficiently to burst the cell wall, but, instead of extruding, will simply tear open. The manner of this tearing is quite characteristic, and suggests at once the appearance obtained on tearing a stiff jelly or the coagulated white-of-egg.(figs. 3, 5).

It is, however, not easy to say precisely what the relation is between the inbibition capacity of the tannin-mass and the insolubility of the tannin.‡ The tannin may be completely extracted from a hard fruit just previous to entering upon the

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*Presumably. I have not investigated this as yet.

‡Since writing this I have succeeded in getting further light on this relation. The results will shortly be published.

ripening, or softening, period by boiling for a sufficiently long time with changes of water, but can not be extracted with either water or alcohol after a point of change is reached some time previous to that when rupturing of the cell may still take place. It would seem that there occurs a brief period when the quantitative relations of the tannin and hypothetical carrier are such as to imprison the whole of the tannin. It may very well be that the loss of fluidity is due to a complete union of the two substances, and that the physical characters of the mass thereafter are peculiar to the compound.

The underlying causes for the remarkable change have been sought for by Vinson (1910). The great variety of chemical agents tried by him to hasten its progress appears to discount the idea that there is a chemical process[*] involving the tannin itself which renders it insoluble. Heat was found to effect the same results, but within the limits usually indicative of enzymotic activity,[‡] and of the cessation of direct protoplasmatic activity. There is nothing in this conclusion, important as it is, to excite wonder. From my observations of the ripening process in persimmons, I am almost of the mind that the death of the protoplasm ensues under normal conditions, at about the time of digestion of the middle lamella, which, as above stated, leads to a final plasmolysis of the cells of the mesocarp. Indeed the secretion of a supposed ferment which may excite the changes in the tannin-cells may be a death character.

As to the possibility of tasting the tannin, it is true that if the pulp is soft, so that a portion may be taken into the mouth without breaking the tannin-cells, the astringency will ensue, as Howard says, only upon their bursting, for obvious reasons. But I think that it is shown that the bursting of these cells is not necessarily followed by detectable astringency, since the tannin may have become wholly insoluble.

In the ultimate condition of dehydration, the tannin mass is sufficiently dense so that it fragments with but a little pressure, but not before it has shown at least a slight resiliency. Coincident with the progressive change toward this state the mass shrinks and becomes either angular (Howard) or lobate

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[*] The color reactions must be taken into account. These may, however, be subsequent to insolubility.

[‡] I may here recall the fact that dehydration and other changes proceed in the digestive tract and in the test tube with pepsin.

The latter condition having been observed by me in a Japanese fruit treated with ethyl nitrite, and may be due to the hastening of the normal processes. The retention of its elastic qualities by the tannin-mass, even in cells which have been washed and dried and again wetted, and in those which have been recovered after normal digestion, is of importance.

The evidence which so far has been offered indicates that the tannin-mass which extrudes is not attacked by water. I must further hold that there is no granulation on contact with water, as described by Howard. I have,to be sure,observed the same appearance said by him to take place, namely, the occurrence ofwhitish particleswhere the extrusion has appeared.(fig.14) This mass is in part protoplasm which is forced out of the cell at the same time as the tannin-mass. One may observe that it contains the carotin masses, which are not to be found in the tannin-mass. Treatment with dilute acids results in the solution (by chemical change) of the tannin-mass, but with the retention of the granular portion without change of form. The appearance of the whitish granulation therefore is independent of the behavior of the tannin-mass. A fuller consideration of the origin of this granular matter must be reserved until more evidence has been gained.

During a condition of considerable hydration, the application of ferric chloride causes shrinkage in the tannin-mass. As Howard has observed, the staining of this proceeds more slowly if the cell is not ruptured. The reason for this is the fact that this reagent does not penetrate the pectocellulose wall*as rapidly as it does the naked tannin-mass. This is proved by my observation that the earliest staining of the tannin-mass in an unruptured cell frequently takes place in the areas opposite the shallow pores in the cell wall. Indeed this is an excellent, although indirect method of demonstrating the presence of these pores. Howard's statement that if the ferric chloride solution is about isotonic with the solution it will burst in the cell can not be of significance in this connection, since a very dilute solution which will cause the cells to burst and extrude their contents will, immediately after the extrusion has proceeded somewhat, cause the tannin-mass to shrink again and withdraw within the cell wall, leaving the granular matter extruding. The tannin-cells are not,

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*The cell-wall reacts blue with iodine.

at this time, in a condition of turgor and the dimensions of the cell wall or of the plasmatic membrane do not change, even with a strong solution of the agent. The behavior toward the ferric chloride,therefore, is due,I believe,to the relation of the tannin-mass to the reagent, and not the cell as a whole, save of course, the interference of the cell-wall to the ferric chloride molecule. It is difficult to believe that tannin, as such and unassociated with a carrier capable of limited imbibition, can behave in this manner. (figs. 7, 8).

The size of the tannin-mass in young and old cells has a similar bearing. No matter how young the cell and how little tannin it may contain (if we may believe that the depth of coloring in reaction to ethyl nitrite indicates amount) the tannin-mass always impinges on the protoplasm except where there occur superficial pits * and other depressions to be accounted for by the presence of the nucleus and differences of thickness of the plasma, strands of it, and, probably, sap-vacuoles independent of the tannin-mass(fig.1). These relations are similar in both old and young cells, and do not affect the bulk of tannin-mass appreciably. This constancy of size of the mass with the constant increase in depth of reaction of the tannin contained in it, seems to indicate that a carrier is present and that its spatial relations are practically constant, while the amount of tannin is not.

I have already, in the paper on the date above mentioned, advanced an explanation for the observation made by Howard and by myself, that intercellular tannin occurs, to the effect that it is due to accident. Any method of treatment of a hard fruit, in which the tannin-masses are still fluid, that will cause the rupture of the tannin-cells, produces, in this way, intercellular tannin. If a block of mesocarp is cut out with a sharp knife with care not to bruise the pulp, and then treated with ethyl nitrite or copper acetate, the tissues to some depth below the cut surfaces will be found injected so that practically all the intercellular spaces are occupied by the expressed tannin mass Fruits which have been bruised always show the same thing when properly prepared for examination. Superficial bruises are easily detected by their brownish color, although the fruit may be firm and there may be no depression at the place of bruising. This change of color is explained by the coloring of the

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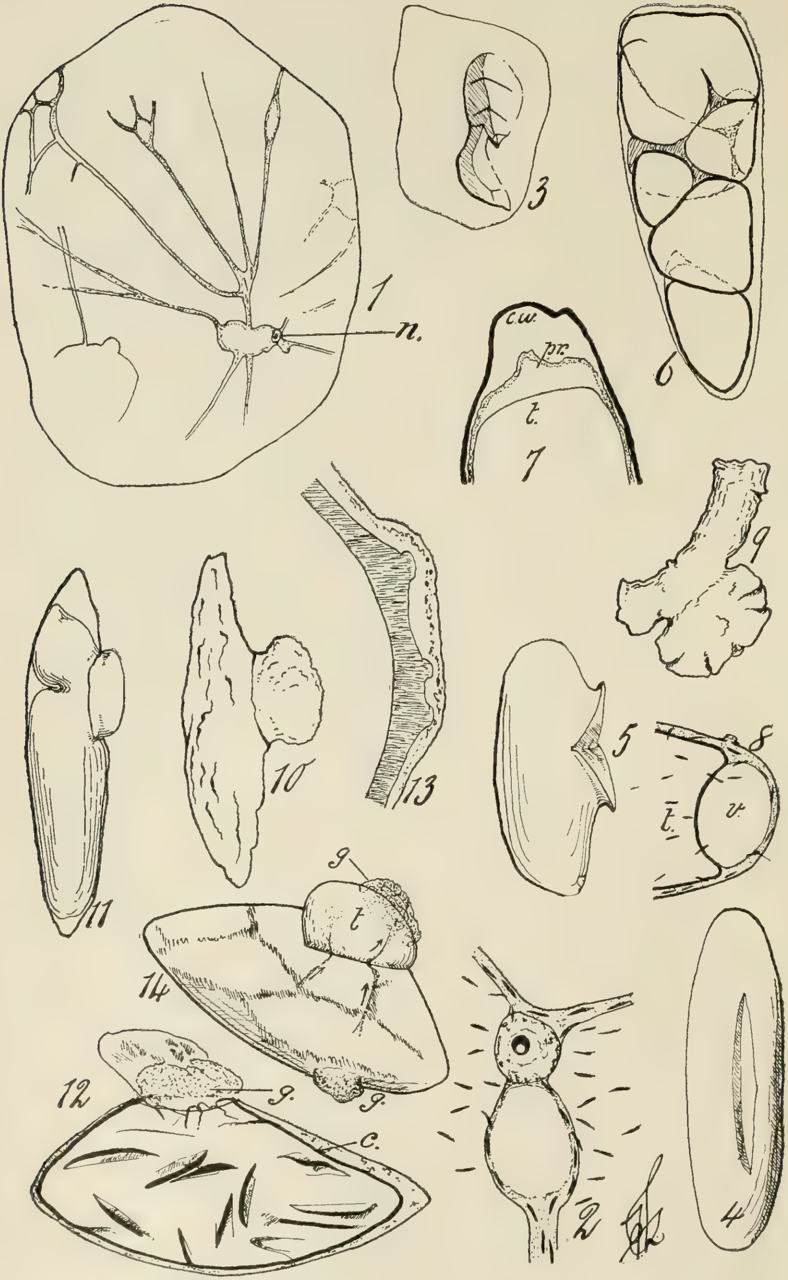
*Called "vacuoles" by Howard. This is not an accepted usage.



LLOYD: TANNIN IN PERSIMMONS.

tannin, both in the unruptured and ruptured cells, and is probably caused by the access of oxygen. During normal advance of ripening no coloration of the tannin-masses occurs. Aso* states the contrary, with whom, however, Howard takes issue, although he finds a few red tannin cells, and gives a photograph of them. It is clear to my own mind that red or brown tannin-cells are such as have early died within the tissue, and become colored by chemical change. Their appearance in Howard's photograph suggests this. I have not seen any colored tannin-cells in untreated fruits which did not have every appearance of being abnormal in this sense.

CONCLUSIONS.

The tannin in the tannin-cells of the persimmon fruit when unripe, is not wholly in a watery, or cell-sap, solution. It is rather associated in part with a carrier in a manner analogous to a gelatin, albumen, or other colloid-tannin union.

The insolubility of tannin, (itself a colloid) in the ripe fruit, is due to its intimate and complete association with this

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Fig. 1. Tannin cell showing the distribution of depressions (pits and canals) in the surface of the tannin-mass occupied by plasmatic structures and sap-vacuoles. (n) Nucleus.
Fig. 2. Detail of the surface depression occupied by nucleus and vacuole. Spindle-shaped carotin bodies in the plasma.

Figs. 3, 4, and 5. Tannin cells which burst and tore in distilled water. Fruit a week after full ripening.

Fig. 6. Tannin cell from a fruit ripened in ethyl nitrite. The tannin-mass has become obular in shrinking.

Fig. 7. End of a cell in a ripened fruit, showing the plasmolysed protoplasm. (t) tannin-mass; (pr) protoplasm; (c.w) cell wall.
Fig. 8. A similar cell after partial swelling of the tannin-mass on being placed in water. (v) sap-vacuole. The turgid condition is due wholly to the pressure exerted by the swelling tannin-mass.

Figs. 9 and 10. Tannin mass after normal digestion, from a completely ripened fruit, which gave, upon eating, no astringency whatever. The cell wall and protoplasm have been digested. The bursting occurred either during mastication or in the stomach.
Fig. 11. A cell which burst after being washed, dried and subsequently placed in water again.
Fig. 12. Tannin-cell after prolonged treatment with dilute nitric acid. The granular mass is still present at (g). Behind it is the portion of the cell wall pushed out during rupturing. A non-tanniferous colloidal shell (c) remains within the cell wall.
Fig. 13. Detail of such a cell, drawn with a camera lucida, showing the colloid shell, protoplasm and cell-wall, from left to right. Optical section.

Fig. 14. Cell bursting in very weak ferric chloride, in which the granular matter may be seen escaping (as indicated by the arrow points) and collecting to form the granular mass, which usually accompanies the extruded tannin-mass. Below, a similar granular mass extruding independently.

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*Quoted by Howard, I have not seen the paper.

carrier, (a second colloid), with which it unites. The behavior of tannin, if this explanation be found ultimately correct, is therefore analogous to that of other substances which are rendered insoluble by combination, *e.g.*,oxalic acid with calcium.

The final stages of ripening are probably independent of living protoplasm at the time during which final softening takes place, and are therefore due to it indirectly. This conclusion is also supported by experiments,not here reported upon specifically, in which chemical agents have been used to induce ripening earlier or more rapidly than is normal.

There is no intercellular tannin in a normal tissue. When such occurs it is due to accident *e.g.*bruising causing the bursting of the tannin-cells *in situ.*

The capacity for imbibition on the part of the tannin-mass sufficient to burst the cell-wall is not associated with astringency to the taste during the whole of the period of ripening when such bursting is possible.

Although aside from the purpose of this paper, evidence is obtained that the cell-walls of the pulp are digested. It has been shown that they are not true cellulose, but pectocellulose.

It is probable, in the light of earlier studies of the date, that the above conclusions are applicable to this fruit also.

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PLANT ACCLIMATIZATION IN SOUTHERN ARIZONA.

J. J. THORNBER.

In a recent paper * on plants capable of successful cultivation in arid regions, the writer discussed briefly a list of native and introduced species, including trees, shrubs and other plants, which after several years of close observation have been found remarkably well suited for growing in the drier parts of the Southwest. For reasons not always clear these plants have displayed notably resistant qualities to all our extremes of climate,as well as to our diverse soils. No matter how hardy plants may be as concerns heat and cold, their failure to withstand other equally important factors, as aridity, means their inability to make healthy or normal growth and ultimately their dying out. The possession of one or more hardy qualities for a plant is not sufficient; it must be strong in its make-up in every essential particular.

A list of highly resistant plants like this must necessarily be limited in our region, where the several factors controlling plant growth are sufficiently pronounced and far-reaching in their effects to render practically impossible the successful growing of a very large number of exotic species, even with good care. Upon examination it is not surprising to find that this list is made up to a very considerable extent of native southwestern plants, which, having become adapted by long continued selection under adverse conditions, are manifestly able to flourish under the same conditions with the added advantages resulting from cultivation.

Plants well suited to our climate, especially among exotics long accustomed to growing under environments widely different from our own, are indeed rare. In fact, only a relatively small percentage of plants having a distribution limited to the cooler or moister sections of the continent flourish in the more arid and heated parts of the Southwest. The failure of such species as these to thrive here, except perchance at the higher altitudes, is scarcely to be wondered at. On the other hand, it is to be noticed with great interest that a very considerable percentage

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*Thornber, J. J. Drought Resistant Plants for the Arid Southwest. Timely Hints for Farmers. No. 83. Ariz. Exp. Sta. Jan 1910 of plants native to arid or semi-desert regions similar to our own, as for example the plants from the Mediterranean region, are almost certain to flourish from the very start with us. This applies not alone to the numerous weeds that have already found their way here without encouragement, but also to various economic species introduced from time to time by man.

So clear-cut are the climatic elements over parts of the Southwest,particularlythose influencing the growth of plants,that modifying by even a few degrees the maximum summer or the minimum winter temperatures,or neutralizing in a small measure the aridness of the fore-summers makes possible the growth of a much large number of species than now obtains. On a small scale this is seen from growing plants under lattice, a practice which is gaining rapidly in parts of the Southwest, and which promises to play an important part in our future horticultural operations. In this manner the conditions of heat, light, cold, and aridity are mollified to greater or lesser extents. It is not the average run of climatic factors, however, such as may be noted by a hasty examination of weather records, but rather the extremes of these, that must be taken into account in the introduction of new plant varieties in a locality, and when these are permanently changed by any means whatever, as by lattice construction, the way is opened for the growing of an adtional list of somewhat less resistant plants. The behavior of plants when grown at different altitudes under similar cultural conditions throws additional light on this matter of varying or modifying the important factors of plant growth, though here the subject is rendered somewhat complex by the addition of other factors, the effects of which cannot be foretold.

In this paper it is desired more especially to call attention to some plants that ordinarily do not thrive under our conditions. If it were possible to make a careful study of all the causes, direct or indirect, contributing to failure among introduced species, the results would be not only interesting scientifically, but of inestimable value to the planter and horticulturist. Such a study would enable one to predict more accurately the probable success of plants when transplanted to other countries, and to guard against the introduction of species that later might become dangerous weeds. In short, it would tend to put the interesting work of plant introduction on a scientific basis. Besides, it would assist in explaining the distribution of the native species over the country, both as concerns vegetation forms and related plant groups.

Not until one makes a study of the fundamental causes underlying plant distribution does he come to a realization of the effects of the various climatic and other factors on the composition of the flora of a region; and this is especially true when plants are included that have come into possession of the land only recently, and hence owe their success to inherent qualities by virtue of which they thrive under the conditions obtaining, and, in the case of weeds, encroach upon the growth of other less energetic plants. It is partly on this account that the introduced plants of a country are invariably an interesting group, those that are poorly suited to the new environments disappearing as quickly as they appear.

It need hardly be said to be appreciated that of the large number of new varieties of plants brought into this country every year for planting only a few become established and continue to flourish. Some fail because of poorly aerated or drained soils, lack of humus or nitrogen in the land, or on account of an excess of alkali present. Others suffer from extremes of summer or winter temperatures or from too strong light. And, finally, even with an abundant and continuous supply of soil moisture, extreme dryness of the air in connection with heat may be so pronounced as to scald or wither the foliage, or to force the plant to give off more water from its leaves through transpiration, than can possibly be taken up by its roots in the same time, with resultant severe wilting during the heat of the day. Both these conditions check normal growth, and if long continued weaken or kill the plant.

With maximum temperatures ranging from 105 to 112 degrees F. during many summer days, usually with extreme aridity, many trees and shrubs are subject to severe leaf scald, and though they continue an existence from year to year they make at best a slow, unsatisfactory growth. Among these may be mentioned tulip tree (*Liriodendron tulipifera*), common catalpa (*Catalpa bignonioides*), sycamore (*Platanus occidentalis*), American linden or basswood (*Tilia americana*), Kentucky coffee tree (*Gymnocladus canadensis*), Norway maple (*Acer platanoides*), sycamore maple (*Acer Pseudo-Platanus*), winged elm (*Ulmus alata*) American elm (*Ulmus americana*), black walnut (*Juglans nigra*), English walnut *Juglans regia*), camphor tree (*Camphora officinalis*), smoke tree (*Rhus cotinus*), white poplar (*Populus alba*), common lilac, common weigela, native red-bud (*Cercis canadensis*), mock orange (*Philadelphus inodorus*), deutzia (*Deutzia scabra*), and snowball (*Viburnum opulus*), besides numerous spiraeas and roses. With these plants growth is usually normal until May or June, after which they are comparatively inactive for the remainder of the season, or in certain instances growth may begin again with the cooler temperatures of late summer and fall. In the summer season, they do not present a healthy appearance.

As concerns herbaceous species it is practically impossible to maintain at the lower altitudes in Arizona during the summer season, stands of such grasses as timothy (*Phleum pratense*), red top (*Agrostis alba*), sheep's fescue (*Festuca ovina*), blue grass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), or smooth brome grass (*Bromus inermis*) even on lawns where far more than ordinary attention is given. No one thinks of growing any of these as hay or meadow plants, although all are hardy grasses in the states to the north and east of us. These species grow fairly well throughout our fall, winter and spring months, but with enough irrigation to make good growth possible under ordinary conditions, their foliage burns and they die out in the summer season, except in the shade of trees or other protection. When several of these species were grown in similar soil under lattice so as to reduce extreme heat and light, they appeared nearly normal; and in parts of Arizona where the maximum temperatures seldom exceed 95 degrees F. they present a thrifty appearance with the usual irrigation. There can be little doubt therefore, that extremes of heat and light, or both these conditions are responsible for the failure of these plants.

This same condition obtains in the instance of such other well-known herbaceous plants as paeonia, dahlia, columbine (*Aquilegia*), golden glow (*Rudbeckia*), gladiolus, grass pink (*Dianthus*), summer hyacinth (*Galtonia*), common tansy (*Tanacetum vulgare*), rosemary or costmint (*Chrysanthemum*), bouncing bet (*Saponaria*), perennial phlox, and perennial larkspur (*Delphinium*), in addition to the garden plants, horse radish, and rhubarb or pieplant. Except under lattice or in the shade of larger plants, these species suffer noticeably during our hot summers, and not uncommonly they die out completely. With partial shade they get through the summer fairly well, after which they make a moderate growth for the remainder of the season. Only rarely, however, do they appear as robust here as in the northern states.

With several trials in various parts of the territory where high summer temperatures prevail, paeonia plants have never blossomed and have generally failed to endure for a single year. Golden-glow and columbine are strictly summer growing species notwithstanding our mild winter climate, native forms of both occurring in our mountains at elevations of 7,000 to 8,000 feet. On the University grounds at Tucson these plants do fairly well during the spring and fall seasons, while in the hot period, June to September inclusive, their leaves scorch badly. Both are showy flowers at Flagstaff, Arizona, where the summer temperatures are comparatively cool. Common tansy, rosemary or costmint, and bouncing bet fail at the lower altitudes with extreme summer heat, and succeed well in the cooler sections at higher altitudes.

The behavior of gladiolus is especially interesting. At Tucson this plant starts growth with the warm days of early March. Except with some protection, however, it seldom gets into flower before it is cut down by the extreme heat of June, the plants wilting badly and scorching, notwithstanding frequent watering. Under these conditions the bulbs do not mature fully and often decay in the ground before being dug. Of 100 bulbs set out by the writer in March 1907, only twelve grew the second season, and a number of these died the following year. Among those that survived the ordeal, for such it was, one has shown notable resistance to heat, blossoming well and making a robust growth each season with heavier than ordinary irrigation. It is quite possible that a strain of gladiolus plants better suited to this climate could be developed from a plant like this.

The early spring bloomers, namely, tulips and bleeding heart (*Dicentra*), also should be mentioned here. Under any conditions the growth of these plants is well out of the way before the hot weather sets in, so that this could have no effect on them. The interval of cool spring weather in our climate between the winter season and the warm dry spring, however, is of too short duration for these plants to be grown successfully. Both have been tried repeatedly, and invariably with failure. Cf 200 tulip bulbs planted by the writer on two occasions only a few ever flowered, and none made good growth the second year. When planted on the north side of a building or under lattice, much better results obtain both as to growth and flowering; even here,however,their growth was far from satisfactory.

Neither horse radish nor rhubarb will grow for any length of time in the hottest parts of Arizona, while in its cooler sections the former at least is quite at home, under irrigation. The Chinese gardeners about Tucson grow a small amount of rhubarb in their gardens from two-year-old plants which are then allowed to die, but it must be said the leaf-stalks are very slender and the results are altogether unsatisfactory.

Among plants grown on a more extensive scale may be mentioned alfalfa and corn. The former is notably a resistant plant and by far our most important cultivated crop. With moderate to heavy irrigation it makes phenomenal growths, being cut six or more times each year. It is stated on good authority that in the Salt River Valley adjacent to Phoenix, Arizona, its growth is noticeably lessened during the hottest summer weather, although the plants suffer no permanent injury therefrom. In the upper Gila Valley in Arizona, where the maximum summer temperatures are several degrees lower, this condition does not obtain. As concerns corn, a plant which makes its fastest growth in the corn states during the hottest summer weather, it yields only moderately with us when planted late enough in the season to make the bulk of its growth during the summer rainy period, July to September inclusive. A small plat of corn under the writer's observation planted in April 1907, failed at best to set more than a few dozen grains on any of the cobs. The plants were irrigated and cultivated twice each week during the hottest weather, nevertheless, in June the leaves wilted badly, "fired" at the tips, and growth ceased. This condition obtained even when the soil was saturated with water, and only by virtue of the greatly lessened transpiration during the night when the equilibrium was restored, were the plants able to live at all.

Such hardy weeds as dooryard plantain and dandelion, ever present in lawns and meadows in the central states, are rarely seen growing in southern Arizona, and then only in the shade of larger plants. These species have been introduced repeatedly in seeds, as careful examination has shown, but at best they die out in May or June before coming to maturity. For the same reason neither common mullein (*Verbascum thapsus*), nor moth mullein (*Verbascum blattaria*), both biennial species from the Old World, grow at our lower altitudes in exposed situations, although both are commonly met with at elevations of 6,000 feet and above.

As concerns the part played by occasional severe freezes in our warmer sections in limiting the number of successful growing species of the introduced flora, only plants from extra-tropical countries need be considered, those from regions farther north being entirely hardy, while tropical plants are, of course, out of the question. There are a considerable number of extra-tropical plants growing in southern Arizona which often endure without injury several mild winters in succession only to be killed later by one much colder than the average, as for example the winter of 1909–1910. Among such plants may be mentioned guava (*Psidium guajava*), kei apple (*Aberia caffra*), St. John's bread (*Ceratonia siliqua*), flame tree (*Sterculia acerifolia*), *Lagunaria Pattersoni*, *Pittosporum undulatum*, *Casuarina equisetifolia*, *Duranta Plumieri*, *Solanum Wendlandii*, *Tecoma capensis*, *Tecoma McKennii*, and *Bougainvillaea spectabilis*, in addition to many palms, bamboos, acacias, and eucalypts. Since none of these can tolerate the severest winter weather in southern Arizona, they are excluded from growing elsewhere in the Territory, except under glass. Curiously enough, with good cultivation, most of these resist well our maximum summer temperatures and but for injury from frosts would prove to be valuable plants in our country.

To summarize briefly, regarding climatic conditions, the ordinary introduced perennial herbs so much grown in the older settled States have not shown pronounced resistance to the extreme heat of our lower altitudes, asparagus being a notable exception; although they commonly thrive at the higher elevations. Many of these are indigenous to countries having cooler growing summers than our own. On the other hand species from countries warmer than our own endure our summer extremes well, although they are subject to severe injury from low winter temperatures and are occasionally killed. Thus far the introduced species that do best under our conditions are those native to regions having similar climatic conditions to our own. Many bulbous plants such as *Narcissus* and *Zephyranthes* thrive with us, growing actively during one season of the year and resting over the other, notwithstanding the usual irrigation. It is well known that many such species as these are indigenous to semi-desert parts of Africa, both north and south, and hence have long been accustomed to climatic conditions quite similar to our own. They represent a type of desert plant, the growth of which is analagous to that of our winter-growing herbs.

It is beyond the limits of this paper to discuss the effects of various soil conditions on the growth of plants. Unlike extremes of heat that are most pronounced in the instance of species native to cool regions, or those of cold which are commonly the deciding factor with extra-tropical plants, soil conditions exert an influence in one way or another on the growth of nearly all species, although this is often scarcely apparent. Not infrequently the physical texture of the soil is such as to prohibit or at least to make uncertain the successful growth of a considerable number of plants. A few examples will have to suffice here. Eucalypts do best in sandy or gravelly soil, in fact, within reasonable limits, the more sandy the better. Such soils are well aerated, free from alkali, and do not become water-logged notwithstanding heavy flooding or irrigating, all of which are essential to success in growing these trees. Among our hardiest eucalypts, as concerns resistance to heat, cold, and aridity, are *Eucalyptus rudis*, *E. rostrata*, and *E. polyanthema*. These, however, will not grow in the presence of any considerable alkali, or in heavy clay or adobe soils, which matter becomes the more pronounced with frequent or heavy irrigation. This explains partly the failure of these plants to grow in numerous instances in southern Arizona. This condition is apparent when scattered individuals over a eucalypt plat, or frequently nearly all the plants become yellow, cease growth, and finally die, while occasional plants more fortunate as concerns soil or drainage conditions continue with foliage dark green in color and vigorous in growth. As a result of the flood waters from the heavy summer showers of 1909, which collected on the University grounds in swales where the soil is naturally heavy, healthy, rapid-growing plants of *Eucalyptus polyanthema* became badly chlorotic and some of them died. On the other hand, the writer has observed very healthy specimens of *Eucalyptus rudis*, which species is most susceptible to chlorosis, growing in very sandy soil along irrigation ditches within six feet of the water's edge. As opposed to the above there are other species like *Brodiaea* and *Calochortus*, native liliaceous plants, that will not grow successfully from year to year in moderately sandy soil, requiring on the other hand, the heaviest clay.

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BOOKS AND CURRENT LITERATURE.

THE CHEMISTRY OF PLANTS.—That the study of plants must become ever more and more chemical in its nature is obvious when one considers that all the plant forms and structures (the mere description and classification of which has mainly occupied botanists to the present time) are the results and tangible evidences of chemical and physico-chemical processes taking place within the organism. Plant morphology must be regarded as a description of the end results of these internal physiological processes, and there can be no doubt that the relationships of structures will receive much light from deeper inquiries into the physical and chemical reactions by which the latter come into being. The present tendency of all lines of botanical study is to become physiological, and of plant physiology to become more and more a search for the fundamental causes of plant phenomena, emphasizes the importance of plant chemistry and plant physics. Every student of plants who hungers for a knowledge of causes, believing with Cicero that *felix qui potuit rerum cognoscere causas*, and who has an eye not only to this "happiness" arising from a knowledge of "the causes of things," but also to the future development of botany, will be glad of the appearance of the second and last volume of Euler's new book on plant chemistry.* If such student feels that his knowledge of chemistry is inadequate to the modern phases of physiology, this work offers a convenient and not too exhaustive introduction to many of the newer problems.

The first of its three parts comprises Vol. I, and is made up of an exceedingly well arranged and very clear series of chemical descriptions of most of the compounds found in plants, from the simpler alcohols to the polypeptides and proteins. The second part, which with Part III, makes Vol. II (as a single volume the book would be scarcely an inch thick). deals with the "general principles of plant life." Here are found discussions of such fundamental principles as osmotic pressure, diffusion, the mass law, solubility, colloids, catalytes and enzyme action, fermentation, the chemical conditions of growth, etc., a knowledge of which will soon be regarded as essential to the serious study of plant physiology, if not, indeed, to that of botany as a whole. The third part treats of the chemical processes in the plant body, such as photosynthesis, the assimilation of nitrogen and of salts, respiration, fertilization in its physico-chemical aspects, respiration, fertilization in its physico-chemical aspects, and the like.

The brevity and clearnesss of the treatment and the characteristic emphasizing of principles rather than facts should make the work much more useful to the student in many ways than has been Czapek's Biochemie der Pflanzen, now six years old. But the completeness of the latter, its very character which makes it difficult of use by the student, will insure the maintenance of its present unique position as a sort of encyclopedia of the chemistry of plants. Euler's literature references are sufficiently full to place the reader in contact with the original sources. It is to be hoped that an English translation may appear at no distant time.—BURTON E. LIVINGSTON.

A NEW PHYSIOLOGICAL TEXT.—The late Professor Barnes, several years ago, reviewed my book on plant physiology with a degree of mercy which I had hardly dared expect, and for which I was correspondingly grateful. I wish that he might now know my appreciation of his success in giving a summary presentation

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***Euler, H, Grundlagen und Ergebnisse der Pflanzenchemie. Vol. I, pp. 239, Vol. II, pp 298; Braunschweig, F. Vieweg & Sohn, 1908-09. [Mk. 13.00].**

of the subject of plant physiology, * but in such a way that the reader not merely feels informed, and is content to wait to be told more, but wishes himself to attempt to solve some of the many problems which Barnes suggests. In the many years during which Barnes had been reading physiology with that rare critical sense which made his work on the *Botanical Gazette* such a valuable contribution to our science, he was accumulating the data and acquiring the sense of proportion which such a book demands. This book shows that his interests were broad, that he had no special hobby which he considered the most important part of physiology to be emphasized accordingly while some other topic was scrimped. The treatment of the different topics bespeaks a mind well balanced as well as mature, able to discriminate between fact and conjecture, honest and humble enough to confess ignorance when pride might have advanced a theory.

Starting from that common point from which one may go to section and speculate in Morphology, or to browse and generalize in Ecology, or to question and experiment in physiology, Barnes first lays the foundation of his discussions in the vegetable cell, its relations to water, the nature, behavior, and actions of aqueous solutions. As far as possible he makes use of the data of physics and chemistry; but while he does not fail to recognize that in certain instances they are inadequate, he does not throw them aside to indulge in vitalistic aviation. Thus he treats of absorption, transfer, and transpiration of water and of the phenomena accompanying and depending upon them.

Distinguishing at once between food materials and foods, he proceeds to expound (though no one can explain) photosynthesis, its products and their ultimate ends. Barnes gave us the word "photosynthesis", but what a short distance physiology has penetrated beneath the surface covered by this descriptive term! The succinct statement of our ignorance of the process of protein synthesis is followed by compact descriptions of special ways of obtaining food, especially nitrogenous food, and of storage, translocation, digestion, and assimilation.

Under the heading Destructive Metabolism, Barnes treats respiration, fermentation, waste products, and ash. I wish the space devoted to the first of these topics had been less brief, for

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*Coulter, John M., Barnes, Charles R., and Cowles, Henry C., A Textbook of Botany for Colleges and Universities. Vol. I, Morphology and Physiology. Pp. 484. New York. American Book Co., 1910. ($2.00).

Barnes had reflected much upon it; but perhaps this space fairly represents the proportion of our actual knowledge to what we know about other phenomena.

The last chapter is named Growth and Movement. In it are treated the phenomena of growth, movement, reproduction, and even death, as affected by external influences upon irritable protoplasm. The treatment is necessarily brief, but it is remarkably clear; there is no confusion of tropisms and taxies, no lack of discrimination between allied phenomena. What the reader does not understand—and it is necessarily much—is from the incompleteness of knowledge and not from the author's slovenly treatment of the subject.

On laying the book aside one can not help feeling renewed grief that our friend was not spared to follow this text-book with the treatise which he was, of American plant physiologists, the one best fitted to write.—GEORGE J. PEIRCE.

NOTES AND COMMENT.

The hundredth anniversary of the birth of Asa Gray, which occurred a few weeks ago, offers a fitting opportunity to recall his distinguished work as a botanist and his greatness as a man. His comprehensive knowledge of American plants, attained through daily studies extending over more than half a century, added to a wide acquiantance with the plants of the world and their distribution, placed him in a position, with his acute perception of generic relationship and his originality of interpretation, to propounnd views that have ever since been fundamental in plant geography. He was among the very first in the New World to receive, cautiously at first, the doctrine of evolution, which he afterward defended with the strength of well founded conviction. During his active service in Harvard University he taught botany, was responsible for the garden and herbarium, wrote the text-books that for a generation were the guide of botanical students throughout the land, and carried forward his monumental work on the American flora. His well balanced judgment and sense of proportion,together with his wide knowledge, contributed to make him "a born reviewer," and during the long period in which he performed this service for the *Ameri-*

can Journal of Arts and Sciences and other periodicals very few things of moment in the botanical world escaped his eye and trenchant pen. His philosophical views were distinguished by a rare clearness and felicity of expression, he had the saving grace of humor, and was a man of such attainment, breadth of view, and true scientific temperament as learned societies throughout the world delighted to honor. The few living botanists who knew him will gladly join in a tribute of veneration and affection to the memory of their worthy leader, aptly named the "Nestor of American Botany."

During the period, but little more than two decades, that has elapsed since the death of Dr. Gray the science of botany has so changed and its limits have become so extended that it may well be doubted that if he were permitted now to attend a meeting of modern botanists he would feel at home. The older generation of botanists now living, many of whom began by "analyzing plants" and learning Gray's Lessons, have seen the development of plant physiology into a science second to none in comprehensiveness, the growth of ecological ideas, the successful experimental demonstration of evolution, the marvelous achievements of plant breeding, the thousand applications of botanical science now made in forestry, horticulture, pathology and other departments of scientific and practical work, and such growth of the broad subject under which these several branches are included that it is no longer possible for any one man to speak authoritatively on more than a limited part of its field. The position of the science in educational institutions and in regard to the demand for those who have taken it up for a life work has been wholly changed. Dr. Gray was accustomed to advise would-be botanists to study medicine, and was frank enough to tell them that if they starved on botany they could still live by their medical practice. At the present day it is the young physician who is in danger of starving, while the botanist is chiefly in danger of being called to a responsible place before he is ready for it.

Of the botanists who began active work within what may perhaps be called the middle period of American botany, and were already well started in their scientific careers before the death of Dr. Gray, few, if any, have made more lasting or more valuable contributions to the growth of botany as a whole or the development of a particular branch of the general science than Professor Charles R. Barnes of the University of Chicago. THE PLANT WORLD wishes to add to the many notices that have appeared in the various journals its tribute of sincere appreciation of the man and his work and sorrow for his loss. The words of his life-long colleague, Professor Coulter, seem to express most fittingly what all must feel. "His loss to his department, his university, and his science, and in all he stood for to his colleagues, and to his students, is simply irreparable. We can face the future with confidence, for a department outlives its men, but a resource that may be placed in amount but never in kind, has now become a memory."

The death of Professor Barnes has necessitated a certain amount of readjustment in the department of which he was the head and which he had brought to so high a degree of efficiency. It is understood that Dr.Crocker will continue to direct the work which he has had in charge for a number of years. Mr. Lee I. Knight has been associated with him, and the study of plant pathology from the standpoint of physiology has been provided for by adding to the staff Dr. Heinrich Hasselbring, formerly of the Bureau of Plant Industry.

Volume 14 Number 2

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

FEBRUARY, 1911

STUDIES IN SOIL PHYSICS.

I. THE PHYSICAL CONDITION OF SOILS. [*]

E. E. FREE.

In the study of the soil certain properties have come to be called "physical" and certain others "chemical," following roughly in their division the fast vanishing line of cleavage between the formal "sciences" of physics and chemistry. It is true that in soil studies these distinctions are even more difficult to define and maintain than in the parent sciences. Soil physics and soil chemistry are but little apart. Pretty nearly any soil problem will have both "physical" and "chemical" aspects and the modern soil investigator must apply to his problems all the "pertinent methods of modern physics, chemistry and biology." [‡] Nevertheless a formal distinction is convenient; and it is useful, although perhaps not necessary, to consider as physical those properties which concern the mutual and external relations of the soil constituents, leaving for separate discussion (under the head of Soil Chemistry) the proximate or ultimate composition of these constituents and the changes therein. Of these physical properties the mechanical are easily the most important. Pore space, mechanical resistance (as to plowing, or to plant roots), the absorption and storage of water and its capillary movement--these and their analogues are the chief physical criteria of soil character. Heat relations have much less importance [||]—optical, electrical and magnetic properties practically none.

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[*] Published by permission of the Secretary of Agriculture.

[‡] Cameron,—Jour. Ind. Eng. Chem., 1, 810 (1909).

[||] Thermal relations are, of course, very important in determining the biological properties of a soil, and temperature has sometimes a considerable effect upon soil water, but these matters must be left for later discussion.

In considering these significant mechanical properties the soil may be regarded as composed of mineral grains, organic substances and water.[*] All the various mineral grains may be classed together, for, although they are of the most diverse minerals and widely different in chemical composition, yet in those of their physical properties which affect the soil they are practically alike. It is these mineral grains which form the framework, the skeleton of the soil. In the laboratory of their interspaces occur the complex chemical and biological reactions which we are just beginning to recognize and to understand. They are the chief materials of soil physics, and the physical effects of water and organic matter are produced by actions upon them. Furthermore, the amount and character of the soil water and the organic matter are variable and more or less under the control of the cultivator. Fundamentally, then, the ultimate physical character of any soil,—its possible physical character,—is determined by the character of its mineral grains, and, as already implied, the specific characters of these mineral grains, are, so far as we know, of little importance. Their important properties are the purely superficial ones of size and shape. The ultimate physical property of soils is therefore the mechanical composition which may be defined as the size and shape of the constituent particles. Obviously the particles of ordinary soils are so widely varied in size and shape that a complete and direct expression of the mechanical composition is impracticable. It is necessary to establish groups of soil particles divided by arbitrary size limits and separated from each other by more or less arbitrary methods. The percentages of the particles of a soil which fall into each of these groups can then be stated as the mechanical analysis.[‡] This is far from a complete statement of mechanical composition Perhaps it is not even the best possible statement.[||] But it is the one in general use and it does give some idea of this fundamental property—the property in accordance with which soils are sands, clays, loams, etc.

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[*] The soil air is excluded from consideration since it represents, so far as physical condition is concerned, simply the empty space of the soil.

[‡] The limits of these groups are purely arbitrary. The system of the U. S. Bureau of Soils (now coming into general use) is as follows: Fine gravel, 2–1 mm. diameter; coarse sand, 1–.05 mm.; medium sand, 0.5–0.25 mm.; fine sand, 0.25–0.1 mm.; very fine sand, 0.1–0.05 mm.; silt, 0.05–0.005 mm.; and clay, below 0.005 mm. For methods of separation see Bulletin No. 24, Bureau of Soils, U. S. Dept. of Agriculture.

[||] In a later paper the author hopes to discuss the errors of the mechanical analysis and the possibility of obtaining a substitute therefor.

But the mechanical composition of a soil does not entirely determine its physical condition. Acting with (and on) it is the structure or the mutual arrangement of the soil particles in space. As this is closer or looser all the physical properties of the soil will vary. By these two quantities, then, the physical condition of the soil is determined; the mechanical composition representing the real or ultimate physical nature of the soil, the structure the physical state in which it exists. [*]

But physical condition is not in itself a measurable quantity or even a quantity at all. It is a complex of many individual properties of the most diverse nature and it is only by observation of these properties that an idea of physical condition is reached. These properties may be roughly classified into two main groups: first, those denoted by texture [‡] which include those related to the amount and size of the interspaces ("porosity," apparent specific gravity, "permeability," etc.); and second, those denoted by mechanical resistance, including cohesion and adhesion, the draft of plows, resistance to penetration and friction, and similar forces. According to this nomenclature physical condition is determined by mechanical composition and by structure, and is evidenced by the properties classed under texture and mechanical resistance. The logical procedure in the study of physical condition is, therefore, the examination of these measurable properties included under texture and mechanical resistance; and the determination, in so far as may be possible, of the ways in which each of them is influenced by mechanical composition and structure and by the external agencies (material and energetic) which control the latter quantity.

TEXTURE. In a dry soil composed of spherical particles of uniform size (the simplest possible mechanical composition) an infinite number of structures are possible, ranging between the closest possible packing, where each sphere touches twelve others, and the loosest possible, where each sphere is in contact with only four others. The percentages of pore space in these cases have been mathematically computed as 25.90 and 47.64, respectively,[*] and these percentages are independent of the size of particles so long as they are uniform. It should be noted, however that variations in the size of spheres will affect the sizes of the individual interspaces if not their total amount,—a matter which becomes of great importance when permeability to be considered. This simple case is, of course, never realized in nature. Practically all soils consist of materials of many different sizes, and the interspaces between the larger grains are partially filled by the smaller. Did no other factors come into play the effect of this mechanical heterogeneity of soils would be to decrease the amount of pore space in all cases. Another modification of the simple conditions arises through the irregularities in the shape of the soil grains, most of them varying widely from the assumed sphere. This irregularity of shape permits both a more complete interlocking of the grains when the arrangement is as close as possible, and a more open structure when it is as loose as possible; thus permitting the existence of masses of non-spherical particles possessing amounts of pore space greater than 47.64 per cent or less than 25.95 per cent. Other things equal, an increased irregularity in the shape of the particles extends, in both directions, the possible range of percentage of pore space.

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[*] By a perhaps somewhat remote analogy the mechanical composition may be called a "quantity" factor (analogous to mass), the structure, a "potential." Or, again by analogy, the mechanical composition is a scalar, the structure a vector.

[‡] I am aware that texture is frequently used as synonymous with mechanical composition. However, such usage is by no means universal and is quite unnecessary since another satisfactory term (mechanical composition) already exists. The use of texture here suggested, namely, as referring to the interspaces, is much more closely analogous to its meaning as applied to textiles, from which source it got into soil literature, and supplies a much needed term for this group of properties. As so used it may be defined as "the expression of the size, arrangement and relative total amount of the interspaces between the soil particles."

It is apparent that these considerations refer only to the range of texture (taking into account both amount of pore space and size of the spaces) which a certain mechanical composition will permit. They tell us nothing of the actual texture which a given soil will possess under given conditions or concerning the texture which will be, so to speak, "normal" to that soil. These are matters of structure, and structure is largely controlled by a constituent not yet discussed—the soil water. The mechanism is as follows: In a moist, but unsaturated soil the water exists mainly in the form of thin films about the soil particles and, where particles touch, the films are also in contact.[‡] At each point of contact the water films fuse, filling the annular space between the particles and forming a water mass of wedge shaped cross-section and bounded by an inwardly curved water-air surface. On this curved surface there will exist (according to well-known laws) a surface tension tending to pull the sides of the wedge together, or in the case of the soil grains, to hold them together at the points of contact. It is these water-film forces which control the formation and persistence of soil aggregates and enable the preservation of more open structure than could endure in the dry soil. They are the determiners of the structure.[*] Without them soils would tend to assume, and in most cases would assume, the closest structure (and therefore texture) which their mechanical composition would allow.

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[*] Slichter,—U. S. Geol. Surv., Ann. Rep. 19. II: 306 et seq. (1899.)

[‡] See Briggs, Bull. 10, Bureau of Soils U. S. Dept. of Agr. (1897).

Furthermore, the nature and strength of these water-film forces will depend upon the water content of the soil. The absolute value of the surface tensions in the wedge-shaped interspaces will depend upon the curvature of the water-air surface, and it is obvious that this curvature will alter as the surface retreats toward or advances from the point of solid contact—that is, as the water films generally decrease or increase in thickness. Now, for a given mechanical composition, the thickness of the water films is directly dependent upon the water content—hence the intimate relation of water content and structure. If a soil be so dry that water films do not exist or are not generally in mutual contact, the surface tension forces will be absent and the structure will depend upon gravity alone. If, on the other hand, the soil be saturated or nearly so, the interspaces will be full of water, the water-air surface and its tensions will disappear and structure will again be controlled in the main by gravity. Over water contents intermediate between dryness and saturation water-film forces will be present and more or less in control, and it is apparent that at some one of these intermediate water contents the water-film forces will have their maximum strength and efficiency and the soil structure (and texture) will be the most open possible. At this point—called the "critical moisture content"—each of the physical properties of the soil (when plotted against water content) shows either a maximum or a minimum.[‡] The openess of texture is, as already stated, at a maximum, and since, other things equal, the maximum openness of texture is also the best for the growth of nearly all useful plants, the critical moisture content assumes a large importance in practical agriculture. *

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[*] Chemically cemented and other relatively permanent aggregates of soil particles are of course excluded from consideration. In their relations to physical condition these aggregates behave like solid particles

[‡] This fact was experimentally discovered before the development of the water film theory of soil structure. See Cameron and Gallagher, Bull. 50, Bureau of Soils, U. S. Dept. of Agriculture (1907)

It is apparent, further, that with a definite mechanical composition there will be for each water content a corresponding structure or arrangement of the particles which may be considered normal therefor. It does not follow, however, that soil in the field always possesses the structure and texture which are normal to it and for the water content which it happens at that moment to hold. Were soil particles perfectly free to move among themselves the soil mass would no doubt always possess the structure theoretically required by its water content, and changes in water content would be followed immediately by the corresponding changes in structure. But soil particles are not free to move. Gravity (in the form of the weight of superposed soil), the adhesion of the grains, the friction between them, and similar factors furnish an inertia which strongly resists any change of structure, especially one which would increase the size or amount of the interspaces. In general, therefore, the actual structure of a soil at any particular moment is not that corresponding to the water content it then holds, but rather that which has resulted from the actions of its various past water contents working against the inertial resistances and complicated by many extraneous factors of which the main are the operations of agriculture. But although a soil does not of itself respond readily to changing amounts of water, if it be stirred artificially, as *e. g.*, by plowing, the structure which it will take on is largely determined by its water content. Hence the importance of conducting cultural operations when the soil is neither too dry nor too wet—when its water content is at or near the "critical" value. The presence of this critical (or optimum) amount of water in a soil does not necessarily mean that the soil then possesses its optimum structure, but does mean that it has then and only then the capacity to take on and retain that structure when stirred.

The water-film forces are by far the most important of the factors influencing soil structure, but there is one other which can not be neglected. In some soils, especially those containing much clay, there are observed phenomena quite analogous to those of colloidal solutions or of the so-called "true" suspensions of fine particles in water.[*] Chief among these is the flocculation or loosening of structure produced on clay soils by added lime. These phenomena are very complex and are still but little understood. It is probable that they are related to surface forces residing on the solid-liquid surface[‡] between the soil particles and the soil water. They are observed only in clay soils but it is probable that they are not confined thereto. There is, indeed, every reason to believe that they are duplicated in kind in all soils at the solid-liquid surface, although in most cases they are entirely masked by the forces at the liquid-gas surface. In these flocculation effects we have, then, a factor affecting structure in all cases but varying in its importance with variations in mechanical composition. In soils composed largely of the coarser particles the interspaces are all relatively large, water-films are set up in all of them and the water-film forces have their maximum effect on structure. In the same soil the amount of solid-liquid surface (in relation to the masses of soil particles and of water) is relatively small and the flocculation effects dependent upon forces there resident are correspondingly unimportant. As the soil becomes finer in mechanical composition the interspaces become smaller and smaller (in individual size, not total amount), in more and more cases the water-films on opposite sides of the interspace come so close together that they fuse entirely, until in the heaviest clay soils the larger proportion of the interspaces are probably too small to contain active water-films at all. The liquid-gas surfaces are nearly absent and their surface tension forces are relatively unimportant. On the other hand, the relative area of this solid-liquid surface has tremendously increased, the forces resident on it are much greater in total amount, and the flocculation which they cause is in control.

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*In many cases the critical moisture content seems to be practically identical with the so-called "optimum water content" as determined by direct experiments with plants. This "optimum water content" is, however, by no means a constant, and depends upon many factors most of which are biological and do not concern the soil at all. The author hopes to treat these matters more fully in a later paper.

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[*] Such systems show a whole series of characteristic properties and reactions of which the most striking is the flocculation, or gathering of the particles into aggregates, which follows the addition of small quantities of most electrolytes. On these matters see Ostwald,—Grundriss der Kolloidchemie, Dresden (1909). For a short summary see Free,—Jour. Frank. Inst., **169**: 421-438; **170**: 46-57 (1910).

[‡] As distinguished from the liquid-gas (water-air) surface. The main items of evidence in favor of the existence of important forces on solid-liquid surfaces are furnished by the phenomena of adsorption, or the concentration of liquids, gases or dissolved substances on the surface of solid particles present in the system. These phenomena seem to have a close relation to those of flocculation. The information concerning adsorption in soils is summarized by Patten and Waggaman,—Bull. 52, Bureau of Soils, U. S. Dept. of Agriculture (1908). On the relation of adsorption and flocculation see Patten,—Trans. Amer. Electrochem. Soc., **9**: 277-290 (1906); **10**: 67-74 (1906); **11**: 387-407 (1907); Freundlich,—Zeits. Phys. Chem., **73**: 385-423 (1910).

All this amounts to saying that if an unflocculated clay soil is moist enough for the setting up of water-films it will be nearly saturated, and this is obviously true. Every farmer knows that a clay soil must be flocculated to be useful, and this flocculation must result from the forces on the solid-liquid surface, not from the water-films. The later are here inoperative because they can not exist.

It should be noted in passing that the importance of the forces at the solid-liquid surface is not confined to the visible flocculations to which they give rise. It is obvious that the water-film forces can draw together the solid grains only because the film is firmly attached to them. There must be between the water film and the soil grain an adhesion stronger than any other forces operative in the system. More than this it is impossible to say. The surface forces of the solid-liquid surface are still so little understood that nearer analysis of the phenomena is not now possible.

It may be well to note also the effect of different mechanical compositions upon the position of the critical moisture content. It is apparent that a soil composed of finer particles has a larger total surface for a given mass of soil. Consequently to set up in this soil mass a water-film system of equal efficiency will require relatively more water. The critical moisture content, when expressed in per cent of water present, will be greater the finer the mechanical composition. In actual fact, experiment has shown that the critical moisture content varies from about three to five per cent (by weight) for sands to thirty or forty per cent for clays. Ordinary loams run from ten to twenty per cent. It is noteworthy that in the finer soils the critical moisture content is less sharp and less well marked than in the coarser—quite what is to be expected, since in these finer soils the water films are relatively inefficient. The forces of the solid-liquid surface (which are then in control) are probably not dependent upon the amount of water present.

MECHANICAL RESISTANCE. The effects which we have agreed to call mechanical resistance are referable practically *in toto* to the friction of the soil particles upon each other or upon a foreign body. It may be that the water-film tensions discussed in the last section are of some effect, but they are certainly far less important than the purely frictional forces. It is to be expected, therefore, that the ordinary laws of solid friction will apply to these phenomena. So little is known, however, of the minute mechanical behavior of the soil that the rigid application of the friction laws is scarcely possible and is certainly useless. The only consideration of practical importance is the number of points at which friction occurs. The soil is discontinuous and friction within it can occur only at the points of solid contact between particle and particle or between the particles and a foreign body. The more such points of contact the greater the friction. Now the number of such contacts is dependent directly and almost exclusively upon the mechanical composition. The finer the soil, the more particles in a given weight; and the more particles, the more contacts. It is true that the structure will have an influence which is sometimes considerable. The more open the soil structure the fewer contacts (on the average) per particle and consequently the less mechanical resistance. A soil already well tilled and of open structure is easier to plow than one which is closely packed. However, the movement against which the frictions are exerted will itself tend to alter the soil structure, and in any case the influence of structure is far exceeded by that of mechanical composition. It is only in the heavier clay soils that the decrease of contact points due to opener structure is sufficient to have a marked effect upon the mechanical resistance. *

ORGANIC MATTER. In all of the above there has been no mention of the third soil constituent—the organic matter. This omission is not only intentional but necessary. Practically nothing is known concerning the nature of the solid organic matter in the soil or its effects upon physical condition. It is known only (and that purely empirically) that the presence of organic matter serves to loosen and make less heavy the heavier clay soils. This effect is probably produced through an influence on the forces at the solid-liquid surface and the flocculations to which they give rise. The mechanism is unknown.

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*This is another kind of mechanical resistance which is of some importance and is not strictly frictional in character. This is the interlocking effect of the grains. It may happen that two soil grains are in such mutual positions that one can not move over the other in the direction required by the applied force without the shearing off of fragments from one particle or the other. The projections from the surfaces of the particles are interlocked. In most cases when this happens the stress is relieved by movements in other directions or by movements of other particles. Only when the soil particles are very angular and very completely interlocked does resistance of this kind become practically important.

SUMMARY.

1. The physical condition of a soil is determined by its mechanical composition and its structure and is made manifest or evidenced by various physical properties which may be divided into those included by texture and by mechanical resistance.

2. The word "texture," as here used, covers those properties related to the interspaces of the soil.

3. The mechanical composition of the soil determines the limits of variation of texture. The actual texture within these limits is determined by structure.

4. Structure (and therefore texture) in any particular soil is controlled by the surface tension forces in the water-films about the soil grains, and by flocculations analogous to those occurring in colloidal solutions and suspensions. The relative influence of these two factors on structure varies with the mechanical composition; the former decreasing, the latter increasing, as the soil becomes finer.

5. In ordinary soils when well stirred the structure and texture depend largely upon the water content and are most loose and open at an intermediate percentage which is called the "critical moisture content." This value depends upon mechanical composition, being higher with increasing fineness.

6. The properties classed as mechanical resistance depend directly and almost exclusively upon the number of contacts between particle and particle in the soil. They are greater the finer the soil.

Of course the importance of these relations is derived from their effects on the conditions of plant growth. These effects may be classified as: first, the indirect effect upon the supply of soil solution and air to the plant roots; and, second, the direct effects of the physical condition of the soil upon root growth. As to these latter it can be said that anything which makes for opener texture and for less mechanical resistance favors plant growth, the importance of texture being probably much greater than that of mechanical resistance. The indirect effects of physical condition upon the water and air of the soil will be discussed in a later paper.

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NOTES ON THE ANCESTRY OF THE BALD CYPRESS.

Edward W. Berry.

It may be stated as an axiomatic fact that when we find a monotypic genus in the existing flora, or one with but few species widely separated geographically from their nearest kin, the genus in question has a most interesting geological history which reaches back into the past much farther than does the ancestry of the horse or the camel, and that at some time the gaps in the present geographical distribution were occupied by the species in question or their immediate ancestors.

Familiar instances of plant survivors of an ancient lineage—extending back sometimes to the remote Paleozoic, will readily suggest themselves. Such a one is the well-known Ginkgo or Maidenhair tree of our parks. Others, like the Sequoia or the Sassafras or the Tulip-tree, are almost equally notable even if they do not reach back quite so far into the past. Another principle which we usually lose sight of when we speak of plant migrations is the fact that present similarities between geographically remote areas do not represent a comparatively recent interchange of species between those areas. What they really show is that a former more or less cosmopolitan distribution has become greatly restricted and the former connecting links in the continuous series of forms have been exterminated in the intervening areas. As a case in point we may take the well-known and often remarked similarity between the floras of eastern Asia and eastern North America. What this has been supposed to represent by plant geographers was a progressive latitudinal migration which might have occurred in an east or west direction from either Europe, Asia, or America as the original starting point. A study of prehistoric floras shows that the preglacial flora of Europe was equally close to that of North America as it was to eastern Asia,with European cypress swamps, with magnolias, tulip trees, sassafras, ginkgoes, torreyas, etc. Then came the Continental ice sheets with the result that from the westernmost point of Spain eastward to the heart of Asia we find that there was an almost continuous barrier cutting off the southward retreat of the flora—the Pyrenees, Alps, Carpathians, Balkans, Caucasus, Altai, and Himalayas, with their locally extended glaciers, with the Mediterranean sea and its Asiastic eastern extensions, and a few arid tracts to complete the chain. In eastern Asia and along the west and east coasts of North America, especially the latter, the mountains, for the most part less elevated than the Eurasiatic chains, trend more or less north and south instead of east and west, consequently a large element was saved to the comparatively impoverished post-glacial flora which would otherwise have suffered great losses as it did in the European and western Asiatic region.

The beautiful Bald Cypress (*Taxodium distichum*) proves no exception to the foregoing statements, in fact the members of the sub-family of conifers to which it belongs (*Taxodieae*) are all remarkable for their present isolation, peculiar distribution and ancient lineage. Four of the genera with only five species in all the existing flora are endemic in the China-Japan region, *Sequoia* occupies its last footing on our Pacific coast, *Arthrotaxus* is Australian and *Taxodium* is eastern North American with a climatically stranded form in Mexico.

When we turn to the geological record we note that no fossil species of Cypress have been recorded with certainty from strata as old as the Cretaceous, although it is quite possible that some of the twigs of conifers which are usually referred to *Sequoia* may really be those of the Cypress, the fact that some of them were deciduous might also suggest this. In the earliest Eocene, however, in the days when the primitive mammalian fauna was replacing the last of the dinosaurs, we find the ancestors of the Cypress with an almost cosmopolitan range. These records are very numerous and are based upon the remains of leafy twigs which seem to have thus early acquired the deciduous character for which their modern descendant is remarkable. Cone scales are also found and sometimes the wood showing the characteristic anatomical features of the genus is preserved. Such an instance is recorded for the basal Eocene of Alberta. In high latitudes we find Eocene records from Siberia, Manchuria, Alaska, Grinnell Land, Greenland, and Spitzbergen. From this northern area the Cypress seems to have spread southward over the western provinces of Canada at least as far as Montana, Wyoming, and Nevada. In the next succeeding geological period, the Oligocene, the records are rather meager if we assume that all of the Arctic Tertiary occurrences are Eocene and not in part Oligocene. There are, however, a number of European records of this age including southern France and the Baltic provinces of the German Empire, from which the Cypress extended eastward into Asiatic Russia. The succeeding Miocene period shows the Cypress extending from Japan on the east to Austria, Switzerland, and Italy on the west. In North America at this time we find the Cypress present in Virginia on the east coast and in Oregon on the west coast. In Virginia the Miocene Cypress seems to have clothed the swamps of the low lying shores; stream flow was sluggish and erosion slight and consequently great beds of diatoms were formed along the coast with but little land-derived sediment in them. In the last period of the Tertiary, the Pliocene, we lack American records* but we

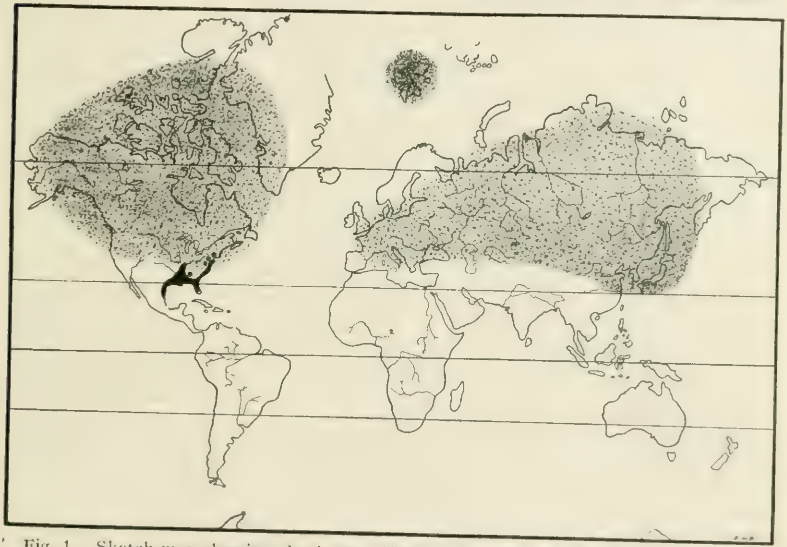

Fig. 1. Sketch map showing the known Tertiary distribution of *Taxodium* [shaded], Pleistocene occurences north of its present limits [dots], and its present distribution [black].

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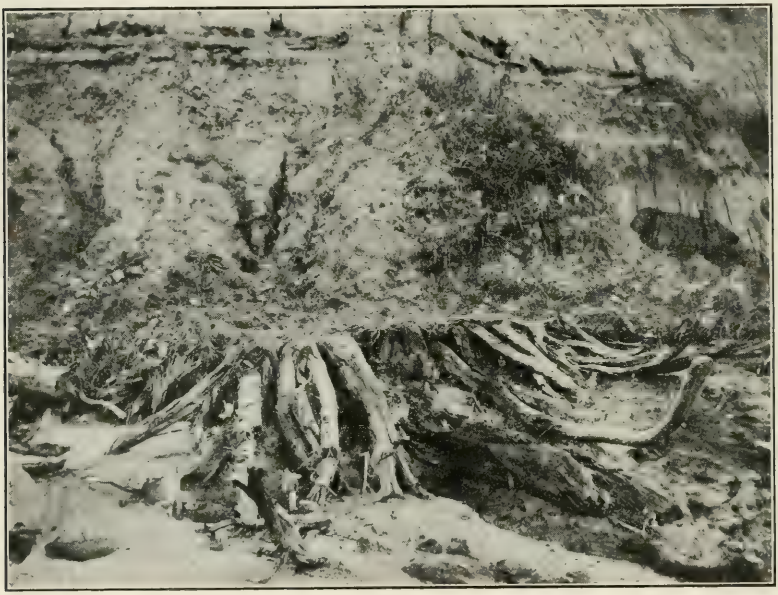
*The writer has recently collected abundant remains of the Cypress from the Pliocene of Alabama.

find the Cypress scarcely if at all distinguishable from the still-existing species as perhaps the most common denizen of the shores of the greatly extended Plaisancien sea which spread over southern Europe and eastward into Asia. The accompanying sketch map (Fig. 1) shows approximately the area over which the Cypress became extended during the Tertiary period.

Following the Tertiary came those climatic changes which ushered in the glacial period of the Pleistocene. Our records of Pleistocene migration are scanty, as might well be imagined, but we know that the Cypress became extinct in Eurasia and that it retreated toward the Gulf region in America, perhaps oscillating southward and again northward with the advance and retreat of the ice front. We do have quite a large number of American Pleistocene records of Cypress based upon the preserved trunks and typical knees like those shown in the figure. The accompanying peat is often packed with the cones and seeds or perhaps a lens of clay may have preserved the deciduous twigs. In one instance the writer collected unmistakable staminate aments from the Pleistocene clays in North Carolina.



Photograph by L. W. Stephenson

Fig. 2. View showing the eroded upper surface of a Pleistocene Cypress swamp overlain by sand and gravel, near Waterview, Virginia.

The remains of one of these Pleistocene swamps has been laid bare by the recent erosion of the Rappahannock river a short distance above the town of Tappahannock, Virginia. The peat which represents the old swamp is exposed for a thickness of four or five feet and is overlain by from fifteen to twenty feet of sand and clay. It contains the remains of other members of the Pleistocene biota in addition to the Cypress, although the latter constitutes the dominant element. Sometimes recognizable leaves are found but usually seeds or fruits furnish the only clue to the identity of the plants associated with the Pleistocene Cypress. At this locality hickory nuts, beech nuts, grape and gum seeds have been collected. Associated with the plant remains are fragments of the elytra of beetles, occasional insect galls and infrequent molluscan shells. Another Pleistocene Cypress swamp is shown in Fig. 2. This is also along the Rappahannock river in Virginia, and is introduced to show the sharp line which separates the old swamp deposit from the overlying sand and gravel. The Cypress roots and stumps recall forcibly those of their recent allies and should be compared with the many reproductions which have been published of the zone of weathered Cypress butts lining the shores of Lake Drummond in the Dismal Swamp. Evidently this region was a sinking one at the time this Pleistocene Cypress swamp flourished, for we can see the progress of events as though the record were a written one; how the estuary waters advanced over the swamp, inhibiting the growth of the seedlings and how the old trees gradually wasted and fell, the waves slowly scouring the surface and depositing their coarse sediments layer upon layer as the land continued to subside. With the final recession of the last ice sheet we find evidence of somewhat warmer climatic conditions than prevail today. This is shown by various subfossil animals and plants collected at certain points from Maryland to Massachusetts as well as by the isolated occurrence of various members or our existing flora many miles to the northward of their normal range. An example of this sort has recently been recorded by Sears in Essex County, Massachusetts. In the Pleistocene records of the Cypress collected by the writer there are five localities north of the present range of the species, that in New Jersey being nearly 150 miles north of the present northern limit. That these facts have more than a local significance is shown by the admirable and exhaustive studies of Scandanavian students who have conclusively demonstrated a considerable northward post-glacial extension, and subsequent retreat of the existing flora. The accompanying sketch map (Fig. 1) shows the Pleistocene stations for the Cypress in the United States and does not include large numbers of buried swamp-deposits in which the presence of the Cypress has not been conclusively demonstrated although the probability of such occurrences is strong. These occurrences may be profitably compared with the present range of the Bald Cypress, shown on the map. That the Cypress is still retreating southward is shown by numerous comparatively recent remains of stumps and knees from numerous localities north of the present range of the species.

Little has been said in the foregoing paragraphs of the modern tree, either of its utility or beauty, although all have been impressed since pre-Revolutionary days, when the traveler Bartram described it as: "in the first order of North American trees. Its majestic stature is surprising. On approaching it we are struck with a kind of awe at beholding the stateliness of its trunk. * * * The delicacy of its color and the texture of its leaves exceed everything in vegetation. * * * Prodigious butresses branch from the trunk on every side, each of which terminate underground in a very large, strong serpentine root, which strikes off and branches every way just under the surface of the earth, and from these roots grow woody cones, called Cypress knees, four, five and six feet high, and from six to eighteen inches and two feet in diameter at the base."

Its remarkably expanded butt and enormously developed "knees" have served to impart to it a weirdness, often enhanced by the shroud of Spanish moss, that would have amply justified a Druidical or similar cult had primitive America only been inhabited by a race which had progressed beyond the stone age of culture.

One of the characteristics of the modern tree which impresses the observer is its great vitality, a feature noticed by Latrobe who, in his description of the Cape Henry sand dunes in 1799, mentions that the Cypress retains life to the last; in other words, until completely buried. One may still see green branches from the tops of trees not wholly buried, although they have been partially buried for a generation or more,since these dunes have moved but little since Latrobe's day. A similar vitality is shown by the patriarchal Cypress groups of Lake Drummond in the Dismal Swamp. The few which remain in the lake are survivors from the day when the water level in the lake was lower and although they are for the most part much wasted and reduced to hollow shells, they still put forth their leafy twigs regularly. A comparable instance was noted by the writer recently along the Chattahoochee river in Georgia. The Cypress is not found along this river except in the lower part of its course, but the variety known as the Pond Cypress is common along various of the tributary streams at least as far up the river as Eufaula. At a point below the mouth of one of these streams very high water had at some time brought in several small but old individuals of the Pond Cypress which had fortunately been left right side up when the waters receded, a seemingly difficult feat in itself, and were apparently not much the worse for having been transferred from their natural surroundings to the narrow shingle of the river-side sand-bar.

The case of the Cypress is not an exceptional one, for every one of our forest trees has an ancestry reaching back some millions of years, and their present structure and habits are a result of ages of adjustment to the maze of interacting environmental forces amid which they have run their race, a fact frequently lost sight of by lovers and students of trees.

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BOOKS AND CURRENT LITERATURE.

THE PLANT LIFE OF MARYLAND.—The appearance of a volume* giving an extensive treatment of the vegetation of Maryland can not fail to attract the attention of everyone interested in regional botanical studies. Of the numerous botanical surveys of special provinces which have been made, few have surpassed this in the careful delineation of the vegetation and the discussion of its fundamental features.

We learn from the introduction (p. 25) that "the principal subject matter of this volume is the Ecological Plant Geography

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***Shreve, Forrest, Chrysler, M. A., Blodgett, F. H., and Besley, F. W.—The Plant Life of Maryland.** pp. 533, plates 39, figs. 15. Maryland Weather Service, Special Publication **Vol. III. Baltimore, 1910.**

of Maryland, which is treated in its general descriptive phases," and (p. 29) that "together with the scientific aim of presenting a picture of the vegetation of Maryland and its distribution, the present work has been carried on with a view to discovering relations between the natural vegetation and the crop possibilities of definite areas."

The Ecological Plant Geography of the Atlantic States is especially interesting in the latitude of Maryland, and applies in a way to all territory between Pennsylvania and Georgia. In all this region one finds the coastal plain, the Piedmont and the Mountain zones, each with distinctly different soils and climatic conditions whose difference is indicated at least by data in this paper showing a mean difference of 115 days between the length of the growing season in the tidewater section and that of the Alleghany Mountain section. (For method of determination, see p. 39). The study of the vegetation was taken up and is described according to these natural divisions of the state.

The plan of the work is as follows: I. Introduction; II. The Floristic Plant Geography of Maryland; III. The Ecological Plant Geography of Maryland; IV. The Relation of Natural Vegetation to Crop Possibilities; V. The Agricultural Features of Maryland; VI. The Forests and their Products; VII. List of Plants Collected or observed.

Dr. Shreve evinces, more than does any other student of Ecological Plant Geography with whose writings I am familiar, the modern idea of the soil as a dynamic and not a static system. Starting with the fact that soils are derived from rocks which almost invariably contain such a variety of chemical elements that the derived soils yield all the inorganic substances necessary for the support of plant life, he proceeds to show how the differences in the vegetation on them may be traced to the operation of dynamic, meteorologic and biological agencies. Also that the presence and kind of soil water are expressed in the plant societies, that the root excretions accumulating in the soil may be unfavorable for the continuance of one plant society, but permit another society to replace it. The vegetation of Maryland is predominantly mesophytic and on the residual soils of the Piedmont Plateau has probably attained as stable a condition as one is apt to find in the Atlantic coast region. Halophytic societies in the salt marshes of the tidewater region and xerophytic societies on the thin soil of the mountain zone form interesting floral groups.

To give an adequate synopsis of the botanical facts presented in this work would exceed the space appropriate for a reviewer. Close study of this region for a number of years has given a greater wealth of observations, accurately recorded, than is likely to appear again in the immediate future. The problems of association and distribution are chiefly treated from the standpoint of the physiographic ecologist, with due weight to the importance of the factors introduced by the cultivation of a large proportion of the country for upwards of 250 years.

Readers familiar with botanico-agricultural subjects may be disappointed with the section of the work dealing with the Relation of Natural Vegetation to Crop Possibilities, at least if very much was expected in the way of specific statements. This is a subject upon which it is all too easy to make over-specific statements, especially if one will allow himself to give credence to the ready remarks of the Oldest Inhabitant type of agriculturist. The more study one gives to this subject, the more probable will be the energetic use of the blue pencil upon his written statements. The following sentences (p. 363) illustrate the point. "The only sound conclusions that may be drawn from the natural plant life of an area as to its agricultural capabilities are very general ones." "That crop recommendations can be profitably made on the basis of the occurrence of a single tree species is doubtful for all but a few cases * * * and these cases may not hold good in other parts of the natural ranges of these trees."

The work closes with a check-list of 1400 species of Pteridophytes and Spermatophytes collected or observed in the state.

It is to be regretted that such an extensive study does not contain more data upon the physical environment of the plants of different provinces. Records of the rate of atmospheric evaporation and of water-holding power of the soil would no doubt be keenly appreciated by the critical student and would certainly enhance the scientific value of a noteworthy piece of work.

The paper is well indexed and illustrated by numerous excellent half-tones, although good maps are scarce and disproportionately small. A careful reading of the work will repay the most critical of students, at the same time its breadth is such that it is highly profitable to all classes and conditions of botanists.—HOWARD S. REED.

BOTANY AND PHARMACOGNOSY.—Botanists appear rather generally to have forgotten that an important portion of their science is comprised in the subject of pharmacognosy. At the present time the application of botany to agriculture is emphasized in almost every botanical department, especially with regard to that portion of mycology which has somewhat gratuitously received the name of plant pathology, and in the new science of plant breeding, but there are comparatively few American university laboratories in which the student ever receives the suggestion that one of the important fields of applied botany and one that is destined to reward research with far-reaching results, is that which deals with the properties and behavior of the drug-producing plants. Just as a physiogical plant pathology and a physiological study of plant inheritance promise much more for the future than the morphological or statistical studies that have heretofore prevailed in these lines, so a physiological study of the nature, occurrence and formation of the chemical compounds of plants promises amply to reward research and to become one of the legitimate and important branches of botanical work.

Readers who agree with the writer in this matter will welcome Kraemer's new edition of his text-book of Botany and Pharmacognosy, which has recently appeared. * While the book could hardly serve as an introductory text for students other than those of pharmacognosy as such, it should nevertheless appeal to the general botanist and especially to the physiologist as a reference book of great value.

After a general treatment of the main characters of the principal groups of plants and of the "outer" and "inner" morphology of the higher forms, the last two chapters of Part I deal with the "Classification of the Angiosperms yielding Vegetable Drugs," and with the;"Cultivation of Medicinal Plants." Interesting treatments of typical drug plants make up a large part of the former of these two chapters, while the latter one considers the propogation of medicinal plants and the collection, curing,

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*Kraemer, Henry. A Text-Book of Botany and Pharmacognosy. Pp. 888. Philadelphia J. B. Lippincott Co., 1910. ($5.00).

and yield of drugs, presenting also a list of cultivated plants which yield substances of value in medicine.

Part II gives full but concise descriptions of the crude and powdered drugs, the former classified as to their morphological origin, as those from seeds, roots, bark, flowers, leaves, etc. The powders are classified first according to color, next according to the presence or absence of calcium oxalate crystals, starch, etc. It is furnished with an apparently usable key for the identification of unknown powders.

Part III treats of reagents and technique for the study of drugs, and Part IV consists of a new departure in a rather thorough crystalographic treatment of plant constituents. Illustrations are numerous throughout the book, and a thoroughgoing index makes the work available as a source for that host of odd bits of pharmacognostical information which the botanist or physiologist sorely needs but which are usually omitted from botanical texts.—BURTON E. LIVINGSTON.

THE TREES AND SHRUBS OF SOUTHERN CALIFORNIA.—Abrams has brought together the results of his field and herbarium studies on the trees and shrubs of the southernmost fourth of California in the form of a systematic list, with complete details of the occurrence and distribution of each form, prefaced by a phytogeographical sketch which adds greatly to the value of the work.[*] The area which has been covered is an extremely diversified one, and in its flora the author notes the occurrence of three elements: the Californian, indigenous to the coastal lowlands; the northern element, present in the mountains; and the desert component, indigenous to the Great Basin or of Mexican desert origin. These distinct floras, making up three quite as distinct types of vegetation, are fitted, as well as can be done, into the scheme of life zones proposed by Merriam. The Upper Sonoran area is shown to include "two distinct sections," the coastal slope and the desert slope. Of the coastal trees and shrubs only ten per cent. occur on the desert slope, while no one of the forms characterizing the desert slope occurs on the coastal excepting *Juniperus californica*, which perversely appears there further down in the Lower Sonoran zone. The mesophilous

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[*] Abrams, LeRoy. A Phytogeographic and Taxonomic Study of the Southern California Trees and Shrubs. Bull. N. Y. Bot. Garden, Vol. 6, pp. 300–485, 10 pls. 1910.

Pseudotsuga macrocarpa is the characteristic tree of the coastal slope, while the xerophilous *Pinus monophylla* and *Juniperus californica*, growing with arborescent yuccas, are the characteristic forms on the desert slope. In other words the two halves of the Upper Sonoran area, considered floristically, have but a trifling percentage of species in common; considered ecologically they have dominant species which are physiologically very unlike. It may well be asked, therefore, wherein the adoption of a ready-made scheme of zones has aided in the exposition of the natural features of the flora in question.—F. S.

FORESTS OF THE GOLD COAST.—H. N. Thompson, Conservator of Forests for Northern Nigeria, has prepared a report on the forests of the Gold Coast Colony which gives a fund of valuable facts regarding a region hitherto little known. * The usual moist conditions of a tropical coast are opposed during several of the winter months by a dry northeast wind (the harmattan) blowing off the Sahara. The coastal belt of evergreen broad-leaved rain-forest is described as being extremely complex in composition and as possessing the usual tropical features. It gives way at localities as little as 40 miles from the sea to monsoon forest, which in turn is rapidly succeeded by savanna forest and by savanna, as the interior of the colony is reached. The rainfall in the coastal belt is 80 inches, that in the monsoon region about 50 inches, and this amount is still found in the savannas of the hinterland 500 miles from the coast, while the humidity falls from a yearly average of 86 per cent. in the monsoon region to 60 per cent. in the savannas. Trees are "practically absent" in the savannas, and in the savanna forest region there is a mingling of large tropophilous and smaller evergreen sclerophyllous trees, with a closed carpet of coarse savanna grasses. Clearings in the forested regions become occupied by the savanna grasses to the subsequent exclusion of trees, the reappearance of which is retarded both by the stature and density of the grass formation and by the annual savanna fires.—F. S.

A PHYSICAL CHEMISTRY TEXT FOR BIOLOGISTS.—The great advances which chemistry has made within the last two decades are no doubt in part the result of several fortunately chosen principles which have served to guide the working out of new ideas and methods; but particularly is this progress to be attributed to the growing tendency to replace the qualitative method of investigation by the quantitative. A recent book by Philip * is designed as a "sketch of the physico-chemical basis for this modern treatment of biological and physiological problems," and is indeed but an introduction to some of the most important subjects of physical chemistry. Most fully treated are: the gas laws, osmotic pressure, electrolytic dissociation, the theory of solution and colloidal solutions. The total avoidance of mathematics necessitates rather lengthy expositions which, however, are written in a very readable style. Each physical chemical principle is illustrated with several most fortunately chosen applications from the biological sciences. The incompleteness of the work, even as an elementary treatment, is striking, as illustrated by the absence of a discussion of chemical equilibrium in a heterogeneous system, hydrolysis and of Faraday's laws, although all of these principles are employed in the exposition of other subjects.—HERMAN A. SPOEHR.

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*Thompson, H. N., Gold Coast, Report on Forests. Colonial Reports—Miscellaneous Cd. 4993. Pp. 238 and map. 1910. (1s. 1d.).

NOTES AND COMMENT.

The arrangement by which Professor R. A. Harper goes to the University of California for the second semester of the present year and Professor G. J. Peirce, of Stanford, takes his place in Wisconsin is one that is to be highly commended, and it is to be hoped and expected that the advantages of such an exchange between botanical departments of American universities will be so manifest as to lead to more frequent arrangements of this kind.

The symposium on plant pathology held at the recent annual meeting of the Botanical Society of America affords some indication of the progress that has been made in this department of investigation within a decade. Time was, not so many years ago, when a student of plant diseases devoted his attention wholly, or almost wholly, to parasitic fungi. Later the study of plant pathology, as indicated by what was undertaken by its most advanced representatives, seemed, in great measure, a

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*Philip, James C.—Physical Chemistry. Its Bearing on Biology and Medecine. London Edwin Arnold, 1910.

matter of the successful isolation and culture of disease-producing bacteria. Today, as well brought out by the participants in the symposium, it is understood that disease is exhibited through abnormal cellular activity and that its satisfactory study can only be accomplished through a thorough knowledge of normal physiology. As to disease resistance, it has become apparent that true resistance is a matter of inheritance and that its production requires practical application of the principles of selection, variation, mutation, etc. The broader conception of plant pathology is thus seen to involve problems of cytology, effects of mineral food, action of enzymes, the chemistry of specific remedies and reactions, the arts of plant culture, the influence of climatic factors, and the special physiology of both host and parasite. It may well be that no single investigator has been or will be able to compass the field thus open, but it is well that such a survey of its boundaries has been made.

In continuation of the notable History of Botany by Sachs, Professor Reynolds Green, of Cambridge, has essayed the onerous task of using the concave mirror to visualize in condensed form the progress of botanical science during the latter half of the century ending in 1900. The leading memoirs have been selected to show the main trend of research, with but little attention to the intensive and reduplicating studies which absorb the activities of so many laboratories. Also, the Atlantic is wide and many sights and sounds familiar to the American make but little impression on the farther shore.

The departures in botanical science are not all attributable to botanists, and the list of names cited for accomplishments, a few of which are clearly trivial or incidental, includes Atkinson, Brewer and Watson, Britton and Brown, Campbell, Chamberlain, Chittenden, Copeland, Draper, Farlow, Fontaine, Golden, Gray, Harper, Jeffrey, Johnson, MacDougal, MacMillan, Newcombe, Osborne, Overton, Peirce, Sargent, Spalding, Ward (L), Webber and Wieland.

That this list would not agree with the results of Professor Cattell's recently compiled statistics of the standing of American men of science goes without saying. One might be compared to the "Blue Book" of New York, and the other to "Who's Who in New York."

Volume 14 Number 3

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

MARCH, 1911

THE INHERITANCE OF HABITAT EFFECTS BY PLANTS.

D. T. MAC DOUGAL.

It is unanimously agreed that organisms, plants as well as animals, change individually in aspect, in form and structure of organs, in functionation and habit as they encounter swamps, saline areas, gravelly uplands or slopes, climatic differences identifiable with latitude or elevation, and other physical and biological factors. It is assumed that these somatic alterations are accommodative and adaptive, making the organism more suitable for the conditions which produce the changes. Such an assumption is an over-reaching one, and it is by no means to be supposed that the plant is a perfectly reacting automaton capable of adjusting itself to every agency which it may encounter.

Any analysis of the changes which an organism undergoes after transportation to a new habitat will disclose one or a few alterations which might be of advantage in dealing with the newly encountered conditions, but with these there are many others, direct, necessitous, atrophic, or hypertrophic as to organs, which have no relation whatever to usefulness or fitness. Thus nearly all broad-leaved plants from the moister regions mature their leaves at smaller dimensions than the normal and this might appear as a fairly direct accommodation. A microscopic examination of these leaves will show that, in some instances at least, the total number of stomata is equal to that of an average leaf, so that the number on any given area is unusually large. The change therefore, would be one reducing the chlorophyll exposure but actually increasing the rate of transpiration for the reduced surface remaining. Similar "misfits"

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*Adapted by the author from Presidential Address on "Organic Response" before the Society of American Naturalists, Ithaca, New York, December 29, 1910. The original text is to be found in the American Naturalist for January, 1911.

in root-systems may be seen, and the observer will avoid many pitfalls by remembering that climatic effects are not necessarily climatic adjustments or adaptations.

We do find however, that the plants of the desert, of the swamp and of the mountain top are so well fitted for these places as to thrive and survive although by no means so perfectly as might be supposed. Some of them grow much better under circumstances wholly new to them . The fact remains, however, that some specialized and fitting characters are to be recognized.

One of the most pressing problems in evolution at the present time is to determine how these and other characters were developed or acquired. Does the plant grown in the desert for a few generations carry xerophytic features when removed to a new habitat or not?

If a general view be taken of the available information some interesting facts will be discerned, obtained by the operations of the horticulturist, the agriculturist, and the breeder, as to the behavior of crops, plants and domestic animals, when transferred from one habitat to another. The greater part of such data is the result of observations which do not comply with the ordinary requirements in the avoidance of error so that strict comparisons as to the behavior of organisms under the conditions of various habitats are impossible. A consideration of this literature yields many suggestions for experimental research and the simple generalization that the direct effects of climatic complexes on the seasonal cycle, and upon color, or structural features of the individual, may be repeated or carried over two or three generations, in a habitat where the specific causal combinations are lacking. This is the available total knowledge furnished us by the economic operations, and by the introduction operations of botanical gardens and plantations.

The awakening of interest in the matter has led to the organization of a great number of experimental researches, during the last decade, and some of the results announced are suggestive and even decisive in some cases.

The recent work of Buchanan with *Streptcocus lacticus* yields the conclusion that phases of fluctuating variations in the bacteria induced by cultures may not be fixed, and are not transmissible, which is in accord with the main body of evidence upon this point. There are, however, a number of records of the appearance of definite qualities or morphological characters in the yeasts, which were transmissible and permanent. These departures were not so striking as to be capable of being regarded as mutational, and their origin has been ascribed to the influence of the environment by experimenters of notable skill, such as Beijerinck, Winogradsky, Lepeschkin, Hansen, and Barber. It may be recalled in this connection that environic responses are generally sudden, and that the entire range of departure may be made in a single generation, at most in two or three.

The recently published work of Pringsheim constitutes one of the most notable contributions to our knowledge of variability among lower organisms. This author, after a comprehensive review of his own work and of other available evidence obtained by a study of accommodations or adaptations of yeasts and bacteria to unusual temperatures, culture media, and poisons, concludes that some of these variations are fixed and transmissible both asexually and by spores, while others are not. It is important to note that the alterations concerned are direct functional responses to the environment.

My own earlier work with relation to this subject consisted chiefly of ovarial treatments in which the main and accessory reproductive elements of seed-plants were subjected to the direct action of solutions of various kinds. New combinations of characters constituting a distinct elementary species or genotype were obtained in one plant, and the divergent type has been found to transmit its qualities in the fullest degree as far as tested to the fifth generation. Still more marked forms were obtained in a second genus, the divergent progeny being lost in transference to the Desert Laboratory, while marked responses have been obtained in the extensions of these experiments upon species representing widely different morphological types in Arizona. The greater majority of the tests have been made upon plants growing under natural conditions, so that environmental reaction in addition to that of the specific reagents, might be excluded. Progenies representing many species, including thousands of individuals, many of which are divergent, are now under observation. Absolute finality of decision with respect to the standing of the new types may be reached but slowly.

Gager produced chromosomic irregularities by the exposure of ovaries of *Oenothera* to radium emanations a few years ago, and some of the progeny from treated parents were aberrant, although the transmissibility of the new characters was not tested.

Klebs, who has long been concerned with the morphogenic reactions of plants, has determined a series of conditions under which the stages of mycelial development, asexual, zoospore, and sexual or oospore formations in filamentous fungi may be inhibited or variously interchanged. Much more important reactions were obtained from *Sempervivum*, the Live-Forever of the garden. In this plant dense rosettes or propagative bodies are formed at the ends of some branches, and inflorescences were replaced by single flowers by experimental excitation; the number and arrangement of the floral organs as well as of the stamens and carpels could be altered. Furthermore, the deviations in question were found to be transmissible in guarded seed-reproductions.

The fortunate experience of Zederbauer with *Capsella* has yielded some conclusions of exceptional importance. A genotype of *Capsella Bursa-pastoris* resembling *C. taraxicafolium* was found on the lower plains of Asia Minor, and displayed the well-known characters of this form, including broad leaves, whitish flowers, and stems 30–40 cm. high. A highway leads from these regions to a plateau at an elevation of 2,000 to 2,400 meters. The conditions of distribution are such as to indicate that the plant has been carried up this thoroughfare by man, and in this elevated habitat it has taken on certain alpine characters, including elongated roots, xerophytic leaves, stems 2–5 cm. high, and reddish flowers, with a noticeable increase of the hairness of the entire plant. That the distributional history has been correctly apprehended seems entirely confirmed by the fact that when seeds are taken from the lowlands the alpine characters enumerated are displayed at once as a direct somatic response. When seeds are taken from plants on the elevated plateau where their ancestors may have been for years many or many centuries, (perhaps as long as 2,000 years) and sowed at Vienna and in other cultures, carried through four generations, the leaves lose their xerophytic form and structure but the other characters are retained within the limits of variability. The stems show an increase in average length of one or two cm., the roots change as much but the reproductive branches and floral organs retain their alpine characters. The silght modifications undergone by these features were seen to reach a maximum and to decrease in the latest generations cultivated. The structural changes and implied functional accommodations are indubitably direct somatic responses, and it is suggested that their annual repetition through the centuries may have resulted in their fixation or permanency.

A related phase of the subject is that of the interposition of environic factors in mutation and hybridization. DeVries has repeatedly called attention to the fact that the composition of hybrid progenies of mutants with each other and with the parental form might be altered by nutritive conditions, and the author has cited the fact that mutations were made by *Oenothera Lamarckiana* in the climate of New York, which had never been seen in Amsterdam. Furthermore, in discussing the divergent results of DeVries and myself, obtained by crossing the same forms in Amsterdam and New York, the suggestion was made that "the manner in which the various qualities in the two parents are grouped in the progeny might be capable of a wide range of variation. Many indications lead to the suggestion that the dominancy and prevalency, latency and recessivity of any character may be more or less influenced by the conditions attendant upon the hybridization; the operative factors might include individual qualities as well as external conditions." Much more striking evidence upon the matter has been recently obtained by Tower in intercrossing species of the potato beetles in their habitats in southern Mexico, and at the Desert Laboratory.

Zoologists have carried out numerous tests on the effects of climate on beetles, butterflies, lizards, crustaceans and mammals with results that vary in detail but confirm the general conclusions to be drawn from plants. From a study of all of the evidence we are warranted in saying that the characters resulting from the action of external conditions, are inherited in many instances. Such heritable qualities may appear at once under the influence of the exciting agency, and thus constitute a mutational change, or the alteration may be gradual and cumulative. In some cases ancestral characters may be caused to reappear, while in others, distinctly new features are induced. The new character may be fixed and permanent from the beginning or may be built up by the repeated action of the exciting agency.

These generalizations are far in advance of any that might have been made five years ago, and the entire subject is attracting the attention and energy of experimentalists all over the world. The plan for work upon the problems in connection with the Department of Botanical Research of the Carnegie Institution of Washington, implies the establishment of experimental cultures in localities which furnish distinct types of climate, or which have characteristic congeries of meteoric factors, as indicated by the vegetation indigenous to them. Secondly, these localities have been chosen with regard to their geographical relations so far as possible, in order that the possible and probable fate of migrating species might be studied. The behavior of plants in these localities is recorded as to anatomical alteration and physiological departure. Having detected some such features of apparent importance, its reappearance in plants from seeds carried to the original habitat and other locations is followed as one line of evaluation. Contemporaneously, the form is taken into the laboratory and here by analytical experimental tests the effort is made to ascertain to what special agencies the departures are due.

Four main locations representing habitats from mountain tops to seashore, have been established in connection with the Desert Laboratory in accordance with this idea, and in addition to the interchange of species from the various localities a number of introductions have been made from eastern America. The results already secured offer much of interest and suggest possibilities of great importance.

Our increased insight into the nature of natural groups of organisms has shown the necessity and suggested the means of observing certain distinctions and precautions in this work. Thus, it is of the greatest importance that the living material shall be shown to be either simple genotypes or that its phaenotypic nature be apprehended in order that the integration and combination of these forms shall not be mistaken for environic effects. When a lot of plants is taken from one plantation to another, data of the original locality are preserved, as the stand of the plant in that place serves as the control. If the plant is multiplied vegetatively in the test, it might reveal a possible complex character of the material in bud sports, but other divergencies might be well ascribed to local effects. On the other hand, if introduced in the form of seeds, the possible complex character of the material would soon become apparent, especially if the generations were followed properly. In the actual management of the cultures, it is found profitable to re-introduce forms from the original or control lot in order to follow the first stages of their adjustment repeatedly.

STUDIES IN SOIL PHYSICS, II.

THE MOVEMENTS OF SOIL WATER. [*]

E. E. FREE.

From a theoretical point of view it is not possible to say that any one of the main soil constituents is more important than any other, since all are necessary to a proper functioning. Practically, however, there can be no two opinions as to the supreme importance of the soil water. Nine times out of ten it is the supply of this constituent which limits crop production. Usually the other constituents are sufficiently, if not maximally, favorable, and poor water supply and infertility go hand in hand. Controlled water usually means controlled fertility. The soil water must occupy, then, a very prominent place in the theories of the soil physicist, and the study of its nature and movements must ever be a most important and absorbing branch of his activity. Nor is the importance of the soil water intrinsic only. It is the medium of the soil solution and only through it are the necessary food elements carried from soil to plant. From soil chemist, as from soil physicist, the soil water is receiving ever increased attention and especially so in the light of the most modern theories of the dynamics of plant food. [‡]

Nearly every discussion of soil water has been based upon a classification which was made very early in the study of the subject. The soil water is divided into hygroscopic, capillary and gravitational, accordingly as it is (1) held in films about the individual soil grains, (2) held by surface tension in the capillary interspaces of the soil, and (3) moving freely under the action of gravity. The statement of this classification in most textbooks is unfortunate in that it suggests, if it does not affirm, the existence of the soil water in three different states or conditions, differing in properties and in usefulness to the plant. This is quite erroneous. The classification is one of forces, not of materials or states, and all the acting forces affect directly or indirectly all of the soil water. It will be better to drop entirely the old terminology, consider the soil water system as a unit, and speak not of hygroscopic, capillary and gravitational water, but of hygroscopic, capillary and gravitational forces. The condition and behavior of the soil water under any given circumstances will depend upon forces belonging to all three of these classes and will be determined by their resultant, not any one of them alone.

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[*] Published by permission of the Secretary of Agriculture

[‡] See, Cameron,—Jour. Phys. Chem., **14**: 320 372, 393-451 (1910).

Hygroscopic forces. The hygroscopic forces are referable directly to the adhesion (whatever that may be) between liquid water and the soil grains. This adhesion is very strong. Thin films of water are (by some mechanism unknown) held very tenaciously by the solid particles of the soil. The measure of this effect, or the hygroscopicity, is of well recognized importance as a soil constant, but as such it will be discussed in a later paper. The importance of the hygroscopic forces for the present discussion lies in that they furnish the attachment or fulcrum for the action of other forces. By them the soil water system is bound to the solid framework of the soil. Obviously water stays in the soil at all only because of the adhesion between it and the soil grains, and it is equally obvious that this adhesion is the strongest of the mechanical forces which affect the system. Capillary or gravitational activities are never able to pull loose the water films from the solid grains.

The capillary movement of soil water.* In the previous paper of this series it was pointed out that in a moist but unsaturated soil the water exists in the form of films about the grains, which films are in union where the solid soil grains touch each other. It was explained that strong surface tension forces exist on the curved water-air surfaces at these

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*The discussion of this section is drawn largely from the papers of Briggs (Bull. 10, Bureau of Soils, U. S. Dept. of Agriculture, 1897) and Buckingham (Bull. 38, *ibid*, 1907).

points of union and that these forces are extremely important in the determination of soil structure. But they have another and not less important influence, namely, that on the movement of soil water. In addition to the pulls exerted on the soil particles to which the films are attached (as explained in the previous paper) there is also a hydrostatic tension exerted upon the water itself and tending to draw more water into the film. The phenomena are quite analogous to the well know rise of water in capillary tubes, except that in the latter case there is only one curved water-air surface, namely, that at the top of the column of water. In the soil the whole water-film system is bounded by these surfaces and the total forces concerned are correspondingly greater. Water will rise much farther in a soil column than in a capillary tube, but in both cases it rises until the total surface tension of the capillary system is just balanced by the weight of the water which has been lifted. Were there no opposing force of gravity the capillary movement of water into a soil would continue to saturation. The individual films of the system tend to thicken because of the tensions on their bounding surfaces, and the whole film system tends to extend itself (by virtue of the "hygroscopic forces," otherwise adhesion) to those particles which had not previously been wetted at all. * There exists, then, because of surface tension or "capillarity," an ever present tendency for the movement of water into soils, a tendency the intensity of which is measured by the total hydrostatic tension of the water films. This tension we shall hereafter call the capillary pressure.‡

But the capillary pressure, like the structural forces of the preceding paper, varies with the thickness of the water films and hence with the water content of the soil. The thicker the individual water films the less is the average curvature of their bounding surfaces, and hence the less is the capillary pressure.|| In any given soil, therefore, the capillary pressure is greater the less the water content already present in the soil. It follows that in a soil of uniform mechanical composition but varied water

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*The first step in this extension of the water system to dry particles is probably a condensation or absorption of water out of the soil atmosphere onto the dry particles. Of course the forces producing this absorption may be included among the hygroscopic forces above mentioned. On the absorption of vapors by soils see Patten and Gallagher, Bull. 51: Bureau of Soils, U. S. Dept. of Agriculture, (1907), and the literature there cited.

‡In calling this force a pressure we must remember that it is applied in a negative direction

||The surface tension on a curved water air surface varies inversely with the radius of curvature of the surface.

content, the capillary pressure will be higher in the dryer spots and less in the wetter. There will be, therefore, a tendency to move water from the wetter spots to the dryer and hence to make the water content uniform throughout. This uniformity is actually attained when sufficient time is allowed and when no other forces are acting. Usually, however, there are other and disturbing forces. The case of capillary rise against gravity has already been mentioned. Here the water content (when rise is complete) will vary continuously from bottom to top. The capillary pressure at any point in the column depends upon the total of the tensions in the film-systems above that point. It decreases with increasing height. On the other hand, the gravitational force acting at any point depends upon the weight of the suspended water below that point, and therefore increases with height. The balance of these capillary and gravitational forces results in the condition stated—a continuous (though not necessarily uniform) decrease of water content from bottom to top. *

Of course the capillary pressure is very intimately related to the general physical nature of the soil and especially to its mechanical composition. When finer particles compose the soil mass not only are there more interspaces and hence more water films, but the tensions of these films are relatively stronger, since their curvature is (in general) greater. It follows ,therefore, that the total capillary pressure of a soil at any given water content will be greater the finer it is in mechanical composition. The finer soil will draw water from the coarser, and when two soils of differing mechanical composition are so juxtaposed that their water film systems are in contact and united the establishment of equilibrium will produce a higher water content in the finer soil than in the coarser. A clay soil can extract water (by capillary movement) from a sand which is far less moist than it (the clay) is. When clay and sand are in "capillary equilibrium" ‡ the former will have many times the water content of the latter. Similarly the height of capillary rise in a clay soil may reach five or six feet while a pure sand will show one foot

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*The continuity of the curve representing water content against height is apparently lost at the top of the column. The decrease in water content is there more abrupt than it should be. This will be discussed below.

‡The condition in which the capillary pressures of the two soil are equal, or, dynamically defined, the condition in which capillary forces will produce no movement of water from one soil to another.

or less.[*] The structure of the soil has also some effect on the capillary pressure. Changes in the size and arrangement of the interspaces will of course affect the nature of the water films in them. But structure is itself a function of water content and its mutual relations with capillary movement and capillary pressures are too complex for analysis here.

In this discussion capillary pressure and the height of capillary rise must not be confused with the velocity of the capillary movement of water. The finer soils show much greater heights of rise but the frictional effects in the individual interspaces are so great that the final height is very slowly attained. Two or three hundred days may be required in a clay as against five days or less for a sand. Similarly in the establishment of all capillary equilibria. The finer the soil the slower are all capillary movements through it. This becomes of great importance when the availability of capillary water to the plant is under discussion.

In the whole of the above it has been tacitly assumed that the absolute surface tension of the soil solution is always the same and that the only variations in capillary pressure are related to differences in the soil or its water content. This is not strictly true. The surface tension of the soil solution is affected both by the temperature and by the dissolved matters which it contains. Rise of temperature always decreases the surface tension; a soil can hold more water when it is warm, and warming frequently causes a soil to lose water which was held by capillarity so long as the temperature was low. On the other hand, most dissolved substances increase the surface tension of water and increase it nearly in proportion to the amount dissolved. The soil solution has, therefore, a higher surface tension than pure water.[‡] Furthermore, if the solution in one part of the soil is of higher concentration than that in another, and if the two solutions are in capillary contact, the weaker solution will lose to the stronger. * There is thus a tendency for the equalization of salt content in different parts of the solution, as there was for equalization of water content in different parts of the soil. This may have great importance to the theories of the movement of plant food materials through the soil, but practically no actual work has been done on these problems and as yet speculation is merely speculation. It is probable also that the organic materials of the soil have important influences on the surface tension of the soil solution and on the forces which depend thereon. ‡ The detailed elucidation of this question must await a more complete knowledge of the nature and properties of the various bodies which make up the "organic matter." ||

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[*] It is a curious fact that the capillary rise in the finest natural clays is never so great as that obtained in fine granular powders (such as mill tailings) formed by artificial grinding and composed of particles relatively much larger than the particles of clay. The cause of this anomolous behavior is not fully known, but it is probably due to some physical change produced by the wetting in the particles of clay. It is conceivable, for instance, that the clay particles swell and close the water passages altogether. See the investigations of Loughridge—Report Calif. Agr. Exp. Station, 1892–94; 91–100

[‡] This is true only of clean, unfouled surfaces. Frequently, however, the surfaces of the soil solution are fouled by thin films of one or another of the oily organic bodies of the soil, and the effective tension of the surface is thus decreased. For this reason the actual tension of the soil solution may be considerably lower than that of water.

The gravitational movement of soil water. Gravity affects the soil water through the weight of the water itself. Like the hygroscopic forces, gravity (in this form) is always active. It is between, and against, the hygroscopic adhesions on one hand and gravity on the other that the capillary forces are acting. More practically important, however, are the effects of gravity in saturated or nearly saturated soils. Here the capillary forces are absent (because there are no water-air surfaces) and the hygroscopic ones are unimportant. The water is moving freely under the action of gravity and in accordance with its own characteristic laws of flow. This is the "gravitational water" of the common classification. The main practical consideration here is the rapidity with which this water will flow through the soil interspaces, *i. e.*, the permeability of the soil. This depends not so much on the total amount of pore space in the soil as on the sizes of the individual spaces. The chief resistances to the flow of the water are frictional and increase greatly with decrease in the cross section of the containing duct. It may easily happen, therefore, that a clay soil containing 40 or 50 per cent of pore space will be almost entirely impermeable while a sand with only 10 or 20 per cent offers an almost negligible resistance to the flowing water. Other things equal, permeability is greater the coarser the mechanical composition of the soil and the looser its texture. Mechanical composition is the controlling factor. In saturated soils there

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*Whether this loss is of water only, or of water plus solute, and in what ratio water and solute are lost, is as yet undetermined.

‡See the last footnote.

||This knowledge is rapidly being acquired: See Schreiner and Shorey, Bull 74, Bureau of Soils, U. S. Dept. of Agriculture (1910).

are no water films to react on the structure and make it looser. The structure tends to be the closest possible, and a soil to be persistently permeable must be composed of fairly large particles. An approach toward uniformity is also favorable. The presence of much smaller material means a clogging of the interspaces and a decrease of permeability.

Evaporation from soils. The loss of water from soils by evaporation takes place practically altogether from the surface of the soil. The atmosphere of a moist soil is always saturated with water or nearly so, but experiment has shown that diffusion of water vapor through it, or out of it into the open air, is very slow. * It is only at the actual soil surface, or within a few inches of it, that any appreciable evaporation takes place. Evaporation has therefore a very close dependence upon capillarity. The evaporation of a little water from, say, the surface inch of a soil decreases the water content of that inch, the capillary pressure increases correspondingly and water is drawn from lower and moister layers to restore the equilibrium. Continued evaporation must, then, be accompanied by continued capillary supply. The motive power lies, of course, in the evaporation, the energy being supplied from without as the heat necessary for vaporization.

Obviously evaporation will be shut off if the capillary supply is interrupted and this is the secret of the so-called "dry mulch." This consists of a layer of dry material of any sort, even dry soil, spread on top of the soil. It constitutes an interruption to the continuity of the capillarity films, breaks, as it were, the pipe through which the water has been coming to the surface, and prevents its further rise. Its efficacy as a water conserver has been amply demonstrated in arid region agriculture and the much talked of "dry farming" methods owe most of their utility to its employment. A mulch may, however, be formed by purely natural processes. When evaporation is intense and capillary supply less so, water may be lost from the surface soil so rapidly that it is not replaced from below and the surface soil dries to the point where the continuity of the water film system is destroyed. This dry layer then acts as a mulch, prevents any further capillary supply, and stops evaporation. There is an apparent inconsistency between this statement and

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*See Buckingham.—Bull. 34. Bureau of Soils, U. S. Dept. of Agriculture (1907).

that on page 62, that the capillary film system tends to extend itself to the adjacent unwetted particles. The harmonization lies in a consideration of the velocities of the several processes. The movement of water onto unwetted material is apparently very much slower than is its movement through film-systems already in existence. There seems to be a considerable passive resistance to wetting. When the surface soil is once dried out it is not easily rewetted and the interstitial evaporation, small though it is, is sufficient to cope with the rewetting tendency of the water below. This is probably also the explanation of the fact noted in the footnote on page 62, that in a soil column into which water has risen by capillarity the decrease of water content at the top limit of rise is more abrupt than is to be expected. [*]

Bureau of Soils,
U. S. Department of Agriculture,
Washington, D. C.

CONIFERS WITHOUT NORMAL WHORLS.

F. J. PHILLIPS.

For some time branchless trees have been known in Europe, especially in Italy and in Baden. Occasional specimens of Norway spruce have been reported without branches but with a slender leader which has long, thick needles and no lateral buds. As a rule these trees die early, but one in Italy has an approximate age of fifty-five years while another noted in Bavaria was eight years old. Two specimens of white fir have also been reported. [‡]

During the past summer a somewhat similar phenomenon was noted on Mexican pinon (*Pinus cembroides* Zucc.) and white fir (*Abies concolor* Parry) in the Huachuca Mountains, which lie along the Mexican boundary in Arizona. A group of eighteen

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[*] This phenomenon could probably be made to yield an experimental proof of the passive resistance to wetting. If there is such a resistance, the height at which water will be held by capillarity in a given soil column ought to be different when equilibrium is approached from above and when it is approached from below. That is, the upper limit of the moist soil should be higher in a column which had been originally saturated and allowed to drain, than in one which had been originally dry and into which water had risen from below. So far as I am aware, there are no reported experiments of sufficient accuracy for the testing of this point.

[‡] "Eine astloste Fichte." Forstwissenschaftliches Centralblatt. January, 1910, pp. 59-60.

Mexican pinon trees from three to six feet tall were found which, although they had made normal growth up to four or five years ago, had not developed whorls since that time. The group of trees occurred on a gentle slope with southern aspect in Duncan Canyon, about one-half mile north of Peterson's ranch and close to the point where the road turns east. The soil is composed of coarse particled conglomerate and porphyry.

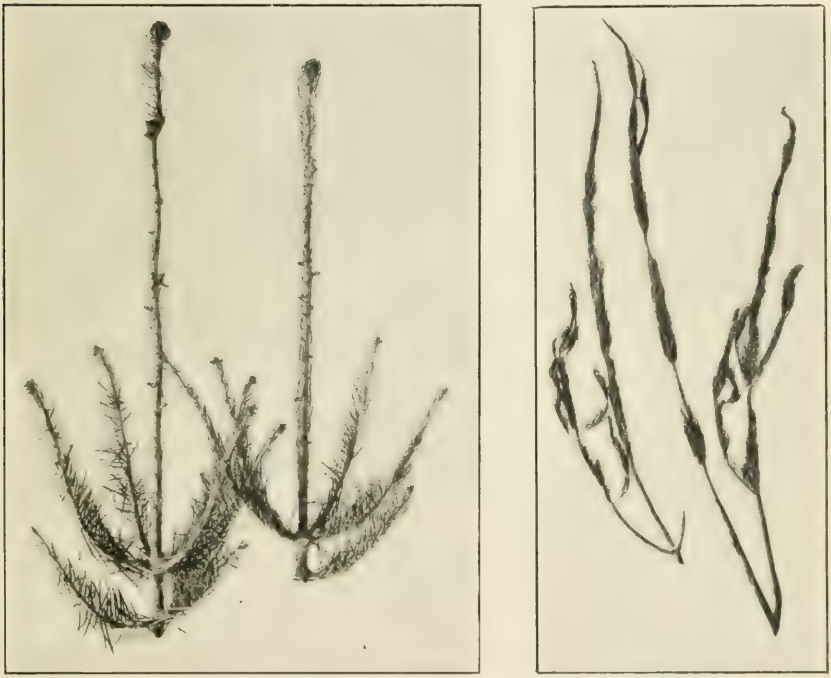

FIG. 1. White Fir without normal whorls for the last three years (left); Leaders of Mexican Pinon showing development without normal whorls (right).

Like the Norway spruce abroad, the needles were slightly longer than on the trees in the same clump which were producing normal whorls. On most of the eighteen trees the needles above the whorls were produced in dense clusters with a bare space between each year's growth, but on at least one of the trees this bare space was wanting. In every case the leaves produced at the beginning of the year's growth were much longer than at the end of the year's growth, which readily served to distinguish where the season's growth had stopped in the tree that had no bare spaces. Needles gradually decreased in length from 1.3

to 1.4 inches in spring to .6 to .8 of an inch at the end of the season. The occurrence of the bare space, however, is not to be considered a result of the lack of whorl development,for the same character was found as a stand characteristic in portions of both the Oro Blanco and the Huachuca mountains. In certain stands, noticeably near Haystack Picacho in the first named mountains, all trees up to and including the oldest veterans showed trimmed Italian garden effect; other stands had only one-fifth to one-third of the trees so developed; in still other stands only rare trees showed any such effect. Cross sections of the bare spaces on the trees failing to develop whorls gave no interior indication of where the whorls ought to be.

Most of these trees showed a single branch coming out after two or three years' failure to produce a whorl. This branch in turn might or might not produce an occasional branch at the end of a year's growth. In one case such a branch appeared to come from the middle of the season's growth while in another case such a branch showing three years without whorls appeared at the base of a tree among a large number of normal whorls. It should be remembered in this connection that all four species of the pinon pines have a strong tendency to produce only one or two branches in a whorl and this is especially true of Mexican pinon along the international boundary. In the eighteen abnormal trees the leaders were only slightly smaller in diameter than on normal trees but on the other hand appeared to have made a more vigorous height growth. Two of these trees with a height of 7.3 feet and 8.1 feet had made a height growth of 4.0 and 4.1 in the last five years when whorls were not being developed.

Two white fir trees respectively three and four feet tall were also found in these mountains showing three years' growth without any whorl development. These trees occurred several miles apart and both grew in the open on moist, rich sites. Up to the last three years the development of whorls had been normal, with four to seven branches at a whorl. Prominent features of both trees were the large, well developed buds scattered along the leaders above the last whorls, shorter needles than on normal trees or on whorls of the same tree, and fewer needles than occur normally on the internode. Above the whorls the needles were also curved more closely about the leader than on other trees or on the lower branches of the same tree.

The University of Nebraska.

BOOKS AND CURRENT LITERATURE.

FOSSIL PLANTS.—It is twelve years since Volume I of Professor Seward's work on Fossil Plants appeared, but no one will complain on that score since Volume II, as the author well says, would have been largely out of date if written ten years ago. * It impresses the writer as being a better book in every way than Volume I. The general plan is the same, the discussion of the fossil forms being preceded in every case by a good account of the living members of the group, amply illustrated. The volume contains a wealth of accurate information which is well up to date, both botanical and paleobotanical literature having evidently been thoroughly digested. There can be no question but what it is the best work of its kind available, more especially for the botanical reader, to whom it should prove indispensable.

The treatment is devoted primarily to Lycopodiaceous and fern-like plants, but opens with the concluding matter regarding the Sphenophyllales, which were not completed in Volume I. The lapse of time makes it possible to describe Scott's work on *Sphenophyllum fertile* and *Cheirostrobus*, two extremely interesting members of this phylum, which enormously extends our knowledge of these ancient plants. Professor Seward is entirely right in not merging the Sphenophyllales in the Equisetales, as some authors have proposed, as he is also in not adopting Professor Bower's proposal to refer the recent Psilotaceae to this Paleozoic phylum. Chapter XIII, the second chapter of Volume II, is devoted to the Psilotales (*Psilotum, Tmesipteris*) and while short, correctly maintains these specialized modern forms as the representatives of a distinct group.

Chapters XIV to XVIII, including some 249 pages, are devoted to the Lycopodiales, using that term in a very general sense. After discussing the recent forms and the curious

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*Seward, A. C.—Fossil Plants, Vol. II, pp. 624, illus. 265. Cambridge, England, 1910. (S. P. Putnam's Sons, $5.00).

Triassic *Pleuromeia*, about which we know so little, the herbaceous species of fossil Lycopodiales are briefly passed in review. A long chapter is devoted to *Lepidodendron* and the genus *Lepidophlois* is merged with it, although the justification for this is not altogether clear. Another chapter is devoted to *Sigillaria*, a type which has received renewed attention in late years. *Stigmaria*, the subject of so many morphological cobwebs occupies an entire and well written chapter, and still another chapter is devoted to the Bothrodendreae. The latter will prove to be the most interesting reading to plant anatomists and physiologists. Chapter XIX is devoted to *Lepidocarpon* and *Miadesmia*, those two remarkable types which the author denominates "seed-bearing plants closely allied to members of the Lycopodiales." Many will question the propriety of terming a sporangium with a retained megaspore "a true seed", as well as the statement that "the Lycopodiales were not always distinguished from Gymnosperms by the absence of seeds," and a still larger number of students will fail to see in these curious Paleozoic forms an argument for the derivation of the Araucarian conifers from the Lycopods.

The next seven chapters, or about half the book, are devoted to fern-like plants, and include a very good account of the recent ferns. An objectionable feature is the separation of the Psaronieae from the Marattiales. for ,while no one will dispute the author's assertion that "it is not impossible that *Psaronius* stems bore fronds which produced Pteridosperm organs of reproduction", this seems to be simply another illustration of the upset mental balance of paleobotanists which the author writes about on p. 282. I presume that it would be unscientific to deny the possibility of *Psaronius* stems having borne artichokes, but one would scarcely conceive such a thing to be within the range of probability.

A new name, the Coenopterideae, is proposed for the Paleozoic ferns familiarly known as the Botryopterideae and the same name is also used at times in a more general sense (Primofilices of Arber). A brief chapter is devoted to the Hydropterideae and the author admits the probability of such an affinity for the widespread Mesozoic forms referred to the genus *Sagenopteris*, a view which has been widely accepted in recent years. The concluding chapter treats of "genera of Pteridosperms, Ferns and Plantae Incertae Sedis." It is quite extensive and is designed to clear the way for the treatment of the better known types in Volume III. This final volume is promised without unnecessary delay and will be looked forward to with a great deal of interest.

The book as a whole is so valuable a compilation that one hesitates to find fault with any of its features. The general plan of these volumes is, however, open to the criticism, admitted by their author, that some forms receive extended treatment while others are ignored, and most individuals will differ regarding the wisdom of any other individual's selections. This feature could be overlooked if the work were designed merely for working paleobotanists, but for botanists and, to a much greater degree, for geologists it is a serious imperfection. The same criticism applies to certain illustrations and comparisons. For example, it might seem from a perusal of page 75 that paleobotanists were in danger of confusing the genera *Veronica*, *Tafalla*, *Lavoisiera*, *Dacrydium*, and *Podocarpus* in the Paleozoic floras, although no such implication is intended. There is also displayed throughout the book a certain iconoclastic attitude regarding the botanical affinity of various fossils which is admirable and necessary to a degree sufficient to offset the more or less imaginary claims of relationship put forward from time to time, but such valid conservatism should not become an attitude of mind whereby the criteria of proof demanded are such as would exclude a goodly proportion of existing plants from the category of proved botanical affinity. This conservatism of Professor Seward goes hand in hand with a very radical "lumping" of similar forms under a single specific name when perhaps their occurrences in time are separated by several million years and their occurrences in space by several thousands of miles. There is also considerable freedom, hardly justified at the present time, in suggesting Pteridospermic affinities for certain Jurassic forms. Finally, in a work where space is so valuable, the reader could well dispense with the information that John Doe discovered such and such a specimen, and other similar irrelevancies, which are not uncommon. The nomenclature also is of a kind which a majority of systematists regard as undesirable. Despite these shortcomings, which may be regarded as secondary in a work of this magnitude, Professor Seward is to be congratulated in pro ducing a book which will be indispensable to any one who is desirous of an acquaintanceship with fossil floras, and it is needless to add that in mechanical workmanship the book is everything that the imprint of the Cambridge University Press implies.—EDWARD W. BERRY.

AIR IN PLANTS.—A recent article by N. Ohno * calls attention to a phenomenon of gas diffusion and the results thereof which may be of considerable importance in plant physiology. He observed that the leaves of the lotus (*Nelumbo nucifera*) continually give off air bubbles from their middle portion during bright sunlight. He proved that the gas is really atmospheric air and that its exudation has no connection with photosynthesis. Conditions which promote evaporation cause an increase in the rate of appearance of these bubbles, which are best seen by placing drops of water on the leaf or by partially filling the cup-shaped receptacle formed by the middle portion. Ohno was also able to measure the gas pressure which forces these bubbles out of the leaf, and found it to rise, under the most favorable conditions, to a magnitude greater than that represented by forty millimeters of a mercury column.

The explanation of the phenomenon appears to rest on that of the observation of Dufour and others, described and explained by Kundt, and referred to in Pfeffer's Physiology, Vol. I, p. 204. The observation and its explanation run as follows. If a porous clay vessel, otherwise closed, be attached to a tube which dips slightly below a free water surface, and if the porous clay be wet with water, alcohol, or some other volatile liquid, air bubbles are seen emerging from the end of the tube and rising in the water. The phenomenon continues long after an amount of air equal to the volume of the vessel has exuded. which shows that this air is in nowise related to the original air in the vessel. A quick way to demonstrate the action is to use alcohol and ignite it on the porous clay. In a few minutes a hundred or two cubic centimeters of air may be collected from a vessel containing no more than fifty cc. To explain the action we consider that the gas pressure outside of the clay chamber is due to a large partial pressure of air and a much smaller one of water vapor, the amount of the latter depending upon the humidity of the air.

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*Ohno, N., Ueber lebhafte Gasausscheidung aus den Blättern von *Nelumbo nucifera* Gaertn. Zeitschr. f. Botanik, 2, heft 10, 641-664, 1910.

Within the porous clay walls the conditions are reversed, and the larger partial pressure is due to water (or alcohol) vapor while the smaller one is due to air. Since the porous clay is permeable to air as well as water, we should expect to find diffusion taking place in both directions through the walls, diffusion of water vapor outward and diffusion of air inward. But the chamber is kept separated with water vapor by evaporation from the surrounding clay, so that the pressure of water vapor remains constant within, and the water vapor which comes off exteriorly is rapidly removed by air currents, so that the pressure of air remains nearly constant without. Since the chamber is open to the outside through the tube, the internal pressure due to air can never rise much above that at the start, for water vapor and air will be pressed out through the water below in the form of bubbles. Water vapor does not move outward through the wet walls as rapidly as air moves inward, and so we have a sort of osmometer with what may be termed a strong solution of water vapor in air on the inside and an extremely weak solution of the same sort on the outside, the membrane being more permeable to the solvent air than to the solute water vapor. Hence the action is a sort of osmosis of gases, a large amount of water vapor being mingled with the air as it exudes from the tube.

In the plant it appears that air is continually entering through the cuticle and stomata and diffusing through the wet membranes into the air channels, thus producing a higher total gas pressure within than without the plant. Apparently the internal pressure rises faster than it can be decreased by outward currents of gas through any other channels that may be open and the main outlet occurs through the porous tissue near the junction of blade and petiole. Any condition which accelerates evaporation tends to prevent the accumulation of water vapor in the vicinity of the leaf, thus at the same time tending to maintain the original high partial pressure of air on the outside. This action is like that of a stirrer in an osmometer, which so mixes the internal solution that it does not become too weak next to the membrane.—BURTON E. LIVINGSTON.

THE SAND DEPOSITS OF ILLINOIS.—Gleason has published a report * of work on several areas in northen Illinois which are characterized by sandy soil derived from glacial outwash. The areas are mainly xerophilous prairies of *Andropogon scoparius, A. furcatus, Leptoloma cognatum, Panicum pseudo-pubescens* and *Koeleria cristata,* with numerous "blow -outs" of nearly bare soil. Along the streams, or extending onto the upland, are belts of forest of *Quercus velutina* or *Quercus macrocarpa.* A number of associations are recognized and the successions are described through which the blow-outs and grassland become forested.

Northern Illinois lies in the transition zone between the deciduous forest region and the prairies of the central states, and just south of the northern coniferous forest region. The author recognizes a successional series for each of these regions and indicates that the vegetational activities of the area he has studied comprise the several successions of the three adjacent regions and also successions in which the deciduous forest series is encroaching on the grassland series; each stage of the grassland series being encroached upon by a corresponding stage of the forest region series.

Gleason lays emphasis on the importance of the "reaction" of the vegetation upon the habitat as being responsible for the successional phenomena observed, saying: "The plant itself is in many cases the controlling agent in the environment." It is of course true of sandy soils, wherever found, that the existence of plants serves to fix them and to increase their organic matter in a manner directly and indirectly favorable to plants of greater water requirement. It is well enough to know what are the effects of plants themselves on the physical environment, but it should be borne in mind that features of the environment which are determined by the existence of associated or precedent plants are, after all, physical in their nature and in no wise different from physical factors of different origin. It can not be true that "undue emphasis on the environment may lead to a partial neglect of the most important feature of a region, the vegetation." No ecologist whose work is known to the reviewer has yet given too much attention to the environment.

Gleason says "the chief difficulty in separating associations lies in the idea of the association itself, which has never been expressed with sufficient clearness." Inasmuch as almost every ecological writer has attempted such an expression the subject bids fair to remain in its present state of turbidity until such time as we cease to go into the field with "ideas" which hamper our work. The framing of definitions and the erection of categories and classifications in ecological work *has* been given too much attention.—F. S.

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*Gleason, H. A., The Vegetation of the Inland Sand Deposits of Illinois. Bull. Ill. State Lab. of Nat. Hist., 9, 21–174, 20 pls. 1910.

VEGETATION OF THE KERMADEC ISLANDS.—Oliver * ahs visited the Kermadec Islands, which lie 1,000 km. to the northeast of New Zealand, and has described their vegetation and flora. A sub-tropical rain-forest predominates, in which the commonest tree is the light-seeded and widely distributed *Metrosideros villosa*. Only 12 endemic forms are found in the islands, while one-third of the total listed flora of 114 species is made up of pteridophytes of wide Polynesian occurrence. The flora is related most closely to that of New Zealand, less closely to the Australian element present in Norfolk and Lord Howe Islands.—F. S.

NOTES AND COMMENT.

A recent paper by Charles A. Davis on the formation of salt marshes (Economic Geology, Vol. V, No. 7) well illustrates the advantage, and even necessity, of botanical training to the working geologist. Salt marshes, as defined by the author, are flat areas, often of considerable lateral extent, so situated that they are overflowed at frequent intervals, typically twice daily at high tide, by salt water. The surface is covered by a growth of a few species of herbaceous plants, of which the dominant and characteristic species are grasses, with some sedges and rushes, and, locally, invasions of other types. It has generally been held that they are formed in shallow water by the upbuilding of the bottom by sediments, until the water is sufficiently shallow for the common ell grass, *Zostera marina*, to become established, and by the encroachment of other species which form a tough, peaty accumulation that builds up nearly to the level reached by high tide; but, from a direct study of over a hundred sections in different marshes and investigations

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*Oliver, Reginald B., The Vegetation of the Kermadec Islands. Trans. New Zealand Inst., **42**: 118–175, 12 pls. 1910.

of the plant remains, the author has reached the conclusion that salt marshes in the area under consideration are features of, and an accompaniment to, coastal subsidence, and also that this type of deposit gives a record that can not be disputed, of the date of subsidence and its uniformity. The rate in eastern Massachusetts has not yet been determined, but is probably slow, perhaps less than a foot in a century.

Mr. F. V. Coville has rendered a useful service in presenting the results of his experiments in blueberry culture (Bur. Pl. Ind. Bull. 193) from which it appears that although the species designated by this name differ fundamentally in their osil requirements from all the common cultivated plants, nevertheless even the swamp blueberry may be very successfully grown in the right kind of soil, as for instance Kalmia peat. Regarding the well known fact that the swamp blueberry and certain other plants, as *Cypripedium acaule* and *Azalea nudiflora*, occur not only in peat bogs but also in sandy upland soil, the author remarks: "The favorite explanation of this phenomenon among botanists is that these plants are naturally adapted to the drier situation and that in the bog they find a situation of 'physiological dryness,' or vice versa. While the existence of physiological dryness in peat bogs is not questioned, the explanation that a bog plant finds an upland situation congenial because it is dry certainly will not answer for the blueberry. Its occurrence on these two habitats is dependent on the acidity of both situations. These experiments have shown that no amount of dryness will make a blueberry flourish in an upland soil if that soil is not acid. Of much interest are the observations on the mycorrizal fungus and its presumed role in transforming the nonavailable nitrogen of peaty soils into a form of nitrogen available for the nourishment of the blueberry plant. The effects of partial shading, the necessity of pollinization by an outside agency, improvement by breeding and selection, and methods of propagation are treated in detail. The paper may be taken as the most complete exposition of the biological requirements of this very interesting plant that has yet appeared.

Botanists who are interested in exchanges should be acquainted with *Herbarium*, an organ for facilitating the exchange of scientific collection of plants, published at intervals by Oswald Weigel in Liepzig, and sent on request to those who will use it. In Number 17, recently received, all sorts of things are offered—Phanerogams of Germany, Cryptogams from British Columbia, Braun's Characeae of Europe, preparations of diatoms, Palaearctic mosses, etc.

In reading the address of the retiring president of the American Association for the Advancement of Science, at the late Minneapolis meeting, one has to admit a lingering doubt as to whether the distinguithed writer would abolish fellowships and the refined methods of laboratory study from modern universities on account of the fact, so cogently presented, that none of these things avail in making a Darwin. If it is true, as Dr. Jordan intimates, that even the presence of abundant facilities will not really interfere with the development of such a genius, may we not rule out these extreme cases and devote ourselves to the problem of making good workers in science, without any effort to square our theories or practice with the extraordinary opportunity, which could never come to most of us, of teaching a Darwin? The real truth seems to be that the great lights of science are a law to themselves, neither made nor unmade by the schools, and that meantime there are actually needed in the United States at the present moment—in the experiment stations, the schools, the scientific bureaus at Washington and elsewhere—an army of trained men, and that this need must be met, if met at all, by doing the best that can be done under the circumstances with the young men and women who present themselves at the universities eager for a career. It would seem to be the part of wisdom to give to all such the very best facilities that the modern art of instruction has discovered, the best appliances of home or foreign instrument makers, the inspiration of contact with great teachers, the opportunity of "meeting nature at first hand," the best special training that each case demands, and then send them out to do the work that is waiting for them. Some at least of those who have tried the method of sitting on a log, with a student at the other end of it, are not yet convinced of its superiority to the means now employed in our best universities.

Botanists and classicists have usually had very little in common as regards either aims or methods, a fact that makes it all the greater pleasure to refer to the notable work of Professor George Hempl, in what may fairly be called one of the higher departments of biological investigation, which is reported by him in part in popular form in the January number of *Harper's*. With a persistence, ingenuity, and application of wide knowledge rarely equaled by any of the great lights in the realm of scientific inquiry, the author shows how, step by step, he has deciphered the written records on tablets and seals of ancient Crete, and has thus aiding in presenting a picture of a civilization antedating Æschylus and Euripides more than a thousand years. Work of this kind constitutes a study of origins, comparable in every essential with that accomplished by botanists who have followed up clues and broked records to definite conclusions regarding the early history of species or floras. To classical workers of this kind we send greetings, and gladly welcome them to the good brotherhood of those who are patiently learning the old story of the earth and its living things.

The citrus growers of California, in a recent convention considered the causes of deterioration of orange groves, the ''average truth''—not always easy to get at in that golden state—appearing to be that, notwithstanding a great increase of acreage, there has been, with the exception of a single year, no material increase of fruit production during the past decade. As is well known, the navel orange, which is the most important for market, is a highly modified variety, and there is every reason to expect that unless it is handled with consummate skill, and under very favorable conditions, it will "run out." Now that the time has come to fully face the problem, orange growers are making earnest inquiry as to the cause, or causes, of decadence and are frankly invoking the aid of scientific men to help them out. At the present the most diverse views prevail. "Inherited weakness," lack of affinity between root and scion, deficiencies in the soil, over-production of fruit, and various other, abnormal conditions are cited, but there is no concensus of opinion, or rather, no actual knowledge, on the subject. It is stated that about one hundred and twenty-five million dollars are invested in the orange and lemon groves of the state. It would appear that, under these circumstances, it might be well to employ a commission of trained experts representing plant breeding, physiology, pathology, and soil investigation to undertake an exhaustive study of the problem.

We have received from Messrs. Henry Holt & Co. a volume of biographies of "Leading American of Science," issued under the editorship of President David Starr Jordan. The biological sciences are represented among the seventeen deceased worthies by Wilson, Audubon, Agassiz, Gray, Goode, and Brooks. The life of Gray, from the hand of Professor John M. Coulter, gives a vivid picture of the conditions which surrounded the profession of botany two generations ago, and of the gigantic work which Gray accomplished in the organization and prosecution of taxonomic work on the plants of the central and western states.

Dr. L. Cockayne announces the appearance, at an early date, of a small volume entitled "New Zealand Plants and Their Story." The prospectus promises an attractive popular presentation of the unique features of the flora and vegetation of the islands, with an abundance of illustrations. The book may be had of the Government Printer, Wellington, N. Z., for four shillings.

Climatic changes in the Southwestern United States within late geological time have been much discussed, and for a subject of importance to the plant geographer there appears, as yet, to be little agreement among those who have given most attention to the subject. The veteran explorer and geologist, Dr. William P. Blake was accustomed to picture an inland sea lapping the base of the Santa Catalinas, the Rincons and other mountain ranges of Southern Arizona, and to hold that the long slopes at their base were formed under water, like those of modern lakes, during a period of maximum precipitation. His successor at the University of Arizona, Professor Tolman, recognizes no such evidence of moist climate and standing water over areas now desert, and invokes wind action and other mechanical agencies to account for their geological and stratigraphical features. Other well known geologists maintain the same view, and the botanists have made such choice of evidence as was possible under the circumstances, choosing, for the most part, the alternative that permitted the view that at all events the plants of the arid Southwest may have occupied their present habitats during a period much longer than that measured by human occupation.

But this comfortable assumption appears to be growing untenable in the light of recent geographical studies conducted in the vicinity of Tucson, Arizona, by Dr. Ellsworth Huntington, of Yale University, whose well known investigations of desert conditions and changes in various parts of the world entitle his opinions, to much respect. His contention is that the Hohokam, or prehistoric "unknown people," lived in such numbers in the Santa Cruz Valley and elsewhere in Southern Arizona as to preclude, at that time, all possibility of such arid conditions as now prevail there. If his view is correct, then the sahuaro, the creosote bush, and other desert plants must at that relatively recent time have lived where they do now under widely different conditions from those now prevailing, or they must have migrated from elsewhere at a still more recent date. Neither supposition is free from difficulty, and farther data are greatly to be desired.

Volume 14 Number 4

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

APRIL, 1911

AMERICAN BOTANY.

GEORGE J. PEIRCE.

I.

As one looks from some fortunate spot upon an extended landscape, details are lost, merged by distance. The interest of the view is in the relation of its parts, their elevations, contours, forms, and distances, rather than in the details themselves. One gains an impression, knowing meanwhile that the whole is the sum of its parts. One may live with a view, may be drawn to visit its special features, may learn its details, may even devote oneself to the study and cultivation of one of them; but in describing the view, one must speak in general terms. Can one give more than impressions, leaving details to the imagination of the listener?

Similarly, if one attempt to speak of American botany as a whole, of its past, its present, and the possibilities of its future, one must attend to proportions rather than to particulars. One must recognize, too, that what we call American botany is such geographically and not intrinsically. It is a part of a whole, and affected by the other parts. American botany has not developed *de novo*, following a spontaneous generation. It is not an instance of the origin of a species by isolation. It came from over sea, it pioneered, established itself, spread; it traveled eastward and grew westward; it reacted to foreign influences and adapted itself to its immediate environment. It has struggled for existence, it has some vestigial characters; but on the whole it is fairly vigorous, fairly prolific organism. Neither in the science of botany nor in its American environment is there reason to fear its extinction. On the contrary there is every reason for confident expectation of increasing prosperity.

So far, however, American botany can not claim to have been any more distinctive than American painting or American music. It has produced no single figure who has discovered any great new principle in Nature or who has established a school unique in its pursuits as in its excellence. There have been, and may now be, competent American botanists of all the well known varieties, taxonomists, plant-geographers, morphologists, cytologists, ecologists, physiologists; but there has developed no variety distinctively American; there is no work which is unique. At the same time that one may be inclined to deny that American botanists are gregarious, reflection shows that they are not so solitary as to be unaffected by botanical fashions But even this trait is not peculiarly American, nor even peculiarly scientific. It is none the less regrettable, however, for while we are successfully metamorphosing from cytologists into Mendelians, then into mutationists, then taking a broad sweep as ecologists and having a fling as physiologists, we are losing, not to say wasting, parts of a single brief life-time and accomplishing less in fact than in printers' ink. There has always been this very human quality about American botanists. Tastes, circumstances, and the mode made them all collectors and describers of flowering plants in the early days of our science. Now plant-breeding, in its various forms, is the latest generally accepted fashion.

There have been little time and little place in this young country for the cultivation of sentimental botany. The first settlers on the Atlantic coast, and the fringe of white men which reached farther and farther westward, needed to know plants for their uses, as yielding food, shelter, and medicine, needed to distinguish the injurious plants and those merely useless. Natural curiosity was sharpened by necessity. From the beginning, the study of plants in this country has been strongly influenced by the requirements of its inhabitants. The devotee of pure science has found scant support and still less understanding sympathy. We may deplore the fact, but we must recognize its adequate and persisting cause.

Botany in this country began with the pioneers, not recognized, perhaps, but nevertheless in reality. The years of exploration were years also of collection, description, experimental cultivation and tentative classification. The romantic figures of Michau and Rafinesque were in much more sober company. It is gratifying to know that many of the older botanists, pure systematists though they were, had gardens as well as herbaria, and studied living plants as assiduously as they preserved the dead. Michaux, Frenchman and explorer, established a garden in Charleston, South Carolina, in which he planted trees and shrubs of his collecting, preliminary to taking such as might be suitable to the Jardin des Plantes in Paris. All traces of this garden seem now to have disappeared, but it and Darlington's near Philadelphia, and Bartram's in Philadelphia, were probably the earliest of a distinctly botanical character in this country. There was, however, an important difference between them perhaps not realized at the time by their makers. Darlington, descendant of a line of Quakers, practicing physician and public spirited citizen of the town and county of Chester, Pennsylvania, interested himself in collecting all the native flowering plants of his neighborhood, and kept them for further study and enjoyment either as dried and mounted specimens, or as inhabitants of his garden. Michaux, on the other hand, foreigner, wanderer, explorer, collected over extensive areas, crossing the mountains into Tennessee and Kentucky and getting the plants which he could keep alive in his acclimatization garden. The Jardin d'Acclimatation of Paris is of later origin than Michaux's, but the aims of its founders were much the same as his. This early difference in botanical gardens has continued to this day; some are established and orderly, others are changing and experimental. Beginning on one coast, they have stretched across the continent in less than a century as private, public, or educational needs and enterprise called them into existence and fostered their development.

The botanical garden of the city of San Francisco, known as the Golden Gate Park, is a fine example of a municipal park conducted on scientific lines and contributing to the scientific as well as to the aesthetic education, and to the enjoyment, of the public. It is not a research garden, nor so intended—in this respect neither a surprise nor a disappointment. Michaux's, Darlington's and Bartrams' gardens were research gardens, particularly Michaux's, and since that time in this country there have always been gardens nominally for research. Most of them, however, increasing in expense if not in extent, and lacking a correspondingly growing income, have maintained their relations to the general public at the sacrifice of their more scientific opportunities. In addition to the experimental plots and farms connected with Government departments, federal and state, there are now, so far as I know, only two gardens exclusively for research, both western, both already yielding more results than could reasonably be expected because of their youth and the arid location of one of them. One wonders if the soil or the "atmosphere" of other gardens is less fertile?

The great names in American botany are those of systematists, the names first of explorers and then of classifiers. With scarcely more than one eminent exception, most of the men of the past generations gained their livelihood by other means, and were botanists because of their devotion to the science. So it was with Englemann, a physician of extensive and exacting practice, Sullivant, Tuckerman, Short, Bartram, Darlington, and, ablest of all, Torrey; men of affairs, physicians, professors of chemistry, of materia medica, or of natural history, by taste botanists, by necessity other things. The one exception is our most eminent man, Asa Gray. Holding a professorship of botany, the Fisher Professorship of Natural History at Harvard, which yielded an income even in that day far from ample, though sufficient to enable him to devote himself wholly to the study of plants and to the cultivation of an interest in that study among our countrymen, Gray lived long enough to see botany develop far beyond the new fields which he was the first in this country to point out.

Gray's life-work was many-sided, much more so than that of any other American botanist. Master of taxonomy, he was the first American, and is still almost the only one to gain general recognition for the importance and value of his ideas on the geographical distribution of plants. Gray's essays on this subject stimulated further work on the present distribution of plants, and inspired renewed inquiry as to their condition in past geologic times. These two more or less divergent lines have led, on the one hand, to repeated attempts to write the geological history of plants on this continent, and on the other, to that undisciplined discipline calling itself ecology. His own endeavors were applied most earnestly to the study of the flowering plants, but he, unlike many of his less broad-minded contemporaries, was not blind to the need of studying the so-called lower forms. He early associated with himself men to whom the cryptogams appealed most strongly. Thus a school of botany was begun, a school to this day with the taxonomic idea preponderant, as for that matter it still is in most of the other botanical schools of this country. The quest for new species is still so frequently stimulated by success that it invariably accompanies the attempt to arrange our plants in classifications more or less reasonable and convenient.

In addition to Gray's great contributions to botanical science, both as classifier and as plant-geographer, we should recognize his records of the personal history of our science in the last century. His obituary notices and biographical sketches appearing in various periodicals, but especially in the successive volumes of the *American Journal of Science*, give in graceful and unusually gracious language the main facts and a personal estimate of the lives and the significance of his contemporaries, thus furnishing the data from which each of us may formulate his own history of botany.

Agassiz was preeminently a teacher by personal contact, and American zoology has been profoundly influenced by him through those whose zeal he enduringly inflamed. In striking contrast to this great teacher by the spoken word was Gray, teacher by his books. How many of us would be botanists now if Gray's textbooks had not been written? These books opened fields far wider than those they cultivated, and to many these opened and untilled fields became the possession and the inspiration of a lifetime. The textbooks of today are different from Gray's, and the proportions of contemporary botany are quite different from those of his lifetime. There has been, perhaps, a greater departure from Gray's botany than from the zoology of Agassiz in the years since they died. But Gray was an inspiring and in no degree a dominating teacher. There is something in this as fine as it is rare. Looking at the botanical schools in this country, one realizes that few of them have been organized on Gray's plan. He recognized that the flowerless plants of America were as important as the flowering, that the anatomy and physiology of plants are as significant as their external morphology and their geographical distribution. He associated with himself men whose chief interests were in these directions, so different from his own, supplementing his and making it possible to study and to teach more nearly the whole than a fragment of botanical science, to study and to teach it with minds centered on the common cause but approaching it from different sides, not uninfluenced but controlled. Gray's greatness shows itself nowhere more planily than in this broad view of the value of other kinds of botanical work than that which most appealed to him and as a contributor to which he attained such merited recognition. We may well hope that more heads of botanical schools in this country, following his broad-minded example, may wisely select their associates and then leave them free to work and to grow according to their own tastes and genius, and the nature of their environment.

II.

What is the status of our science today in this country? In contrast to that concentration on exploration and description which prevailed in the first period, and on taxonomy in the period which followed it, we have today a degree of differentiation among the pursuits of American botanists which could scarcely be exceeded. But as already stated, in this we are following, not to say imitating, Europe. Palaeobotany has long found its most congenial residence in England, pure taxonomy at Kew, and plant-geography at Berlin, while the leaders in Cytology are well distributed over central and western Europe, and the physiologists seem fairly limited to lands of German speech. Space would fail for cataloging the different brands of present-day botanists, from those who work only on the desicated or paraffine-permeated or fossil remains of once living plants, to those who breed, inoculate, and torture to learn the laws of succession, health, and development; from those to whom none but the microscopic or even ultra-microscopic is interesting, to those who make the forest not only the temple of nature but the servant of man, clothing the watersheds, checking the floods, and providing him with houses and furniture. How can one catalogue and classify such diversity? All these aims and enthusiasms of European botanists are cultivated here. This is natural, for many American botanists received their training and their greatest inspiration from German scholars. It is too soon, and perhaps the world has become too small, to expect America to produce a botany, any more than a painting or music or drama of its own. It has its share to contribute to the science, the art, and the literature of the world. If it do this well, it will fulfill its chief duty.

The mechanical means which it has developed in laboratory, experiment-house, apparatus, and journals, costing so much time, thought, and money for mere operation, must not be allowed to be ends in themselves, though keenly appreciated and even occasionally taken back as models to Europe. And that idea of usefulness is the most intelligent which recognizes the race to have been most benefited, during the centuries of its development, by those who studied nature with no other motive than to learn her secrets whatever they might be, whether of lightning, steam, or the evolution of living things. The main things are the spirit of devotion to one's science, and that training which founds one's studies firmly and guides them truly. On the enthusiasm and on the education of American botanists depend their present achievements and their future usefulness.

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INHERITANCE OF FASCIATION IN *ZEA MAYS*. *

HENRI HUS AND A. W. MURDOCK.

Though the question of the inheritance of teratological characters readily lends itself to experimental investigation, the ground does not appear to have been covered so thoroughly that the detailed study of individual cases is entirely without interest. All malformations are not inherited, nor would we expect this to be the case. No one seriously would advance the view that galls, for instance, could be transmitted to the offspring, *i. e.* that the production of galls could be a character inherent in the seed. For many other teratological characters, such as fasciation, inheritance generally is conceded, though instances are not lacking in which this transmission has been disputed and even, in experiment, apparently has been shown not to exist. † However, it is to be noted that, in the case of *Opuntia*, the existence of pseudo-fasciations has been observed by Trinchieri, ‡ and that in such cases we would not expect the character to be inherited.

Even when teratological characters are transmitted, they are not always transmitted to the same degree. Unfortunately this last statement does not present the true aspect of the case and is, in fact, misleading. When we say a teratological character, such as fasciation for instance, is inherited by a percentage of the offspring only, we really mean that the character was visible only in this percentage of the offspring. If the experiment is not carried farther, we are in the dark as to the nature of the plants which do not show a broadening of the stem or of the inflorescence. For the becoming evident of a fasciation may depend on several external circumstances, generally speaking those which influence nutrition.** Similarly, bifurcation in certain ferns, as shown by Heilbronn[*] for *Aspidium filix mas* var. *grandiceps*, does not make its appearance in the first or second leaf but as a rule only in the fourth or fifth. In *Athyrium filix femina* var. *multifidum* the cristation only appears with the sixth or eighth leaf.

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*Contribution No. 120 from the Botanical Department of the University of Michigan.

†Fobe, F. Ueber die sogenannten Hahnenkammformen bei den Kakteen. *Monatschr. f. Kakteenkunde*, 16: 87, 1906.

‡Trinchieri, G. Fasciation et "Pseudo-fasciation." *Atti dell, Acad. Gioenia di Sc. nat. in Catania*, 1907. Trans. G. Renaudet. Soc. d. *Nat. luxemb.*, 1910.

**Géneau de Lamarliére, L. Sur la production expérimentale de tiges et d'inflorescences fasciées. *Compt. Rend.*, 128: 1601, 1899.

Hus, H. Fasciation in *Oxalis crenata* and experimental production of fasciations. *Ann. Rep. Missouri Botanical Garden*, 17: 147, 1906 .

If the seed of a fasciated biennial or perennial be sown so early as to permit the plants to produce an inflorescence during the first year of their existence, it is most probable that no fasciation will make its appearance. In perennials the fasciated character will probably become evident in the second year. But it must be remembered that excellent culture may cause a biennial to flower during the first year and even produce fasciations, as was done by De Vries with *Aster tripolium fasciatum*.[†] In our experiments, plants, the offspring of a fasciated plant of *Delphinium hybridum*, which in the fall of the first year produced a to all appearances, normal inflorescence, showed during the early part of the next year fasciated inflorescences in nearly every instance. But not all of the inflorescences which were produced by these same plants in the fall of the second year were fasciated, though a number of well developed fasciations occurred. This would lead one to establish a connection between the amount of food available and the degree of fasciation. The same thing was noted in our experiment garden in the case of *Hieracium virosum fasciatum*. Plants raised from seed of fasciated individuals produced inflorescences during the first year, but none were fasciated. The second year, however, every inflorescence showed well developed fasciations. And while it may be a matter of indifference whether a perennial produces a desired monstrosity during the first year or during the second, it is otherwise where biennials are concerned. If, for instance, the seed of a fasciated biennial be sown so early as to produce an inflorescence the same year, as has been said, it is generally the experience that no fasciation makes its appearance. But if the culture be arranged so as to bring about the flowering during the second year, then the fasciation will occur. The general rule to be observed is: the longer the period from roset to inflorescence, the greater the chance of fasciation becoming manifest. De Vries * reached similar conclusions with *Dipsacus sylvestris torsus.*

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[*] Heilbronn, A. Apogamie, Bastardierung und Erblichkeitsverhältnisse bei einigen Farnen *Flora*, 101: 1, 1910.

[†] de Vries, H. Sur la culture des fasciations des espéces annuelles et bisannuelles. *Rev. gen. de Bot.*, 11: 136, 1899.

When the experiment is carried further and we take the seed of the non-fasciated individuals and sow it, we obtain a third generation in which, given the same favorable conditions under which we raised the second generation, numerous fasciated individuals will make their appearance. Again using a fasciated strain of *Delphinium hybridum* for purposes of illustration, it was found that no appreciable difference could be noted in the percentage of fasciation in plants raised respectively from seed obtained from fasciated spring inflorescences, from spring inflorescences of plants which showed no fasciation, or from non-fasciated autumn inflorescences of plants which had shown fasciation during the spring. In other words, the fasciated character was latent in the non-fasciated members of the second generation as well as in the fall inflorescences which showed no external signs of fasciation.†

It is even possible for the fasciated character to become latent for several generations as shown by de Vries for *Tetragonia expansa*, *Helianthus annuus* and *Picris hieracioides*.‡ To the author of the MutationTheory we owe the recognition of the true state of affairs. As the result of his extensive and painstaking experiments with fasciated races,he comes to the conclusion that: "the atavists or non-fasciated specimens of the race are to be considered as reversions (Rückschläge) in a morphological sense, *i. e.*, that in their importance for the inheritance of fasciations, they are but little (nur unwesentlich) inferior to the best heirs of the race." ** De Vries also points out that the percentage of fasciations is governed in the most marked degree by the conditions of life. "Das betreffende Verhältniss ist im höchsten Grade von der Lebenslage abhängig; diese kann Atavisten in Erben und Erben in Atavisten umändern. Selbstverständlich

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*de Vries, H. Sur la culture des monstrosités. *Compt. Rend.*, 128: 125, 1899.

*It is, in our opinion, immaterial in the present discussion whether we look upon fasciation as due to the presence, in the nucleus, of a certain "unit," or to a so-called predisposition to fasciation.

*de Vries, H. Die Mutationstheorie, 2: 560, 1903.

**loc. cit.* 542.

findet die Umänderung in der sensiblen Periode der Jugend statt, bevor das betreffende Merkmal sich ausbildet." [*]

Whether such a juvenile sensitive period really exists in all cases is a question. Undoubtedly it does when we are dealing with annuals, as shown by the experiments of De Vries on fasciations. It is a matter of fluctuating variability, to be compared with the variation in the number of stigmatic rays in *Papaver Rhoeas* due to external conditions,[†] or the variation of the number of ray flowers in *Centaurea Cyanus*,[‡] Another instance is yielded by the increase of the number of pistillodous stamens, under favorable conditions, in *Papaver somniferum polycephalum.* [**] But since perennial plants may produce non-fasciated inflorescences after having produced fasciated ones, as in the case of *Delphinium hybridum*, the absence of the fasciation can not be taken to mean a latency of the character due to unfavorable conditions during the juvenile sensitive period. Or are we perhaps to interpret the "juvenile sensitive period" as referring to the earlier stages of development of a particular part of the plant, *i. e.*, that part in which the fasciation appears, and not to those of the plant itself? Experiments are now being conducted on the influence of unfavorable conditions in the early stages of development on the percentage of fasciation in biennials and perennials.

Another instance of the latency of fasciation during one generation is given by de Vries[††] for *Zea Mays*, in which case the latency probably was due to unfavorable conditions. But in succeeding years, when the opposite was the case, he obtained a comparatively high percentage (about 20% and 37%) of fasciations. Now it may be observed that a single corn plant may produce both a fasciated and a non-fasciated ear. In our experiments the following results were obtained:

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[*] *loc. cit.* 567.

[*] MacLeod, J. Over de veranderlykheid van het aantal stempelstralen by Papaver. *Hand. VI. Nat. en Gen. Congr.*, 4: 11, 1900.

[*] MacLeod, J. Over de gevoelige periode van den invloed der voeding op het aantal randbloemen by de korenbloem (*Centaurea Cyanus*) *Hand VI. Nat. en Gen. Congr.*, 6: 420, 1902.

[*] **de Vries, H.** Plant-Breeding, 302. 1907.

[*] **de Vries, H.** Over de erfelykheid der fasciatien. *Bot. Jaarb. Dodonea*, 6: 94, 1894.

TABLE I. SHOWING INHERITANCE OF FASCIATION OF THE EARS OF ZEA MAYS EVERTA.

	Fasciated						Normal	
	11310 Red		11510 White		Totals		11410 White	
	#	%	#	%	#	%	#	%
Plants with all ears fasciated.........	14	64	8	29	22	44	0	0
Plants with some ears fasciated......	2	9	13	46	15	30	1	6*
Plants with no ears fasciated.........	6	27	7	25	13	26	16	94
Total number plants with fasciated ears	16	73	21	75	37	74	1	6
Total number of plants..............	22	100	28	100	50	100	17	100

Evidently plants and not ears must be taken into consideration. For while in the one case(No.11310)the plants with all ears fasciated were in the majority (87.50% of all plants showing fasciated ears), in the case of No. 11510 the opposite occurred, *i. e.*, most of the plants which showed fasciated ears had both fasciated and non-fasciated female inflorescences (62% of all plants showing fasciated ears), while only 38% showed all ears fasciated.

One frequently meets with fasciated ears in cornfields, and these are readily obtainable, more particularly of *Zea Mays everta*. Hence, when the opportunity offered in connection with some other experiments, an attempt was made to determine the degree of inheritance of fasciation in corn. One normal ear of a yellow variety (No. 11410), one fasciated ear of the same yellow variety (No. 11510) and one fasciated ear of a red variety of *Zea Mays everta* (No. 11310) were selected for seed, the ears being obtained commercially. The degree to which these ears were fasciated may be judged from fig. 1, in which the ear on the left was the parent of those under No. 11510.

Of the normal yellow popcorn (No. 11410) were obtained seventeen plants. No fasciated ears appeared, unless we except a single underdeveloped component of a compound ear, referred to above Compound ears are not of uncommon occurrence in *Zea Mays.* * They constitute a mere branching of the inflorescence to which occasional reference can be found as to Gramineae in general and *Zea Mays* in particular, † and are comparable to those found in *Triticum turgidum compositum,* commonly known as Egyptian or Smyrna wheat. But in the latter the branched character never is lost entirely, though it may be greatly reduced under unfavorable conditions.

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*This figure is obtained from a plant which bore two ears, one of which, well developed was not fasciated. The second ear was compound, consisting of a main ear and two lesser, auxiliary ears, one of which was not ripe at the time of collection and had a total length of about 4 cm. It was somewhat flattened. This flattening we interpret as fasciation, though for the sake of our argument it would obviously have been to our advantage not to do so.

It is well known that fasciations have a tendency to split, especially when the crest assumes great proportions, *i. e.*, when the cross section becomes a mere fraction of the width. In a paper shortly to be published, the senior author hopes to bring out the purely mechanical basis for such splitting. For the present purpose it is sufficient to point out that if a splitting may occur during the later stages of development it is not at all improbable that instances may occur in which the same necessary conditions obtain during a younger stage. In *Delphinium hybridum fasciatum* splitting of the inflorescence occurs not un

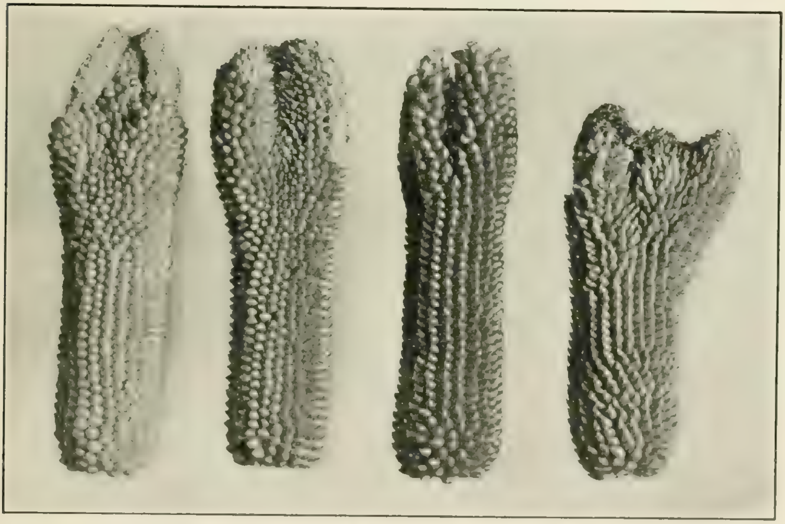

Fig. 1. Fasciated Ears of *Zea Mays everta* ×½.

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*Blaringhem, L. Hérédité d'anomalies florales présentées par le *Zea Mays tunicata.* *Compt. Rend. hebd. Soc. Biol.,* 57: 578, 1904.

†Gallardo, A. Notas fitoteratologicas. *Com. mus. nac. Buenos Aires,* 1: 110, 1899.
de Vries, H. Plant Breeding, fig. 33.

frequently. Thus one of the flowerstalks of a plant showing fasciation in six of its nine flowerstalks, was split eighteen inches from the top, the divisions bearing respectively nineteen and twenty-three flowers. As a rule the splitting occurs very much nearer the top. Of fourteen split inflorescences, ten were split within two inches from the top, one at five, one at eight, one at eleven, and one at eighteen inches from the top. This would militate against the assumption that the branching of the female inflorescence in corn was in any way related to fasciation. Nor do all compound ears show fasciation, though in our experience they did in the majority of instances, as shown in the following table.

TABLE II, SHOWING THE RELATION BETWEEN FASCIATION AND COMPOUND EARS IN ZEA MAYS EVERTA.

	11310	11510	Total
Compound ears totally fasciated	5	13	18
Compound ears partially fasciated	1	9	10
Compound ears not fasciated	0	15	15
Total number of compound ears	6	37	43
Number of ears of all kinds	41	96	137

At the same time the fact that compound ears were also present in No. 11410 (non-fasciated stock) to the extent of 16% need not necessarily invalidate a contention that fasciation and branching are to be looked upon as due to an identical cause, for among the ancestors of these plants may well have been a fasciated ear, something rendered more probable by the fact that one of the components of one compound ear showed flattening (table 1). Further, in the case of the ears under No. 11310, there was not a single compound ear which did not show some fasciation, which would indicate a close correlation between branching of the inflorescence and fasciation. This correlation is not so marked in the case of the ears under No. 11510. But even here 59% of the compound ears showed fasciation while of the single ears under this number only 46% were fasciated. In connection with this the question might be raised whethere th pressure exerted upon compound ears might have a tendency to either cause fasciation or to bring about its simulation. The experiRents of Lopriore * and others show the former to be highly improbable,though Sorauer† notes fasciation in a stem of *Tecoma radicans* due to appression to a wall and of which the part reaching above the wall likewise showed fasciation. In view of other experiments carried on by us it seems unlikely that the pressure exerted would cause a malformation similar in appearance to a fasciation.

The relation between simple and compound ears is well shown in the following table:

TABLE III, SHOWING RELATION BETWEEN SIMPLE AND COMPOUND EARS IN ZEA MAYS EVERTA.

	Simple ears				Compound ears				Summation				Ears not classed *	Total ears	
	Fasciated		Non-fasciated		Fasciated		Non-fasciated		Fasciated		Non-fasciated				
	#	%	#	%	#	%	#	%	#	%	#	%		#	%
11310 Red fasciated....	22	54	12	29	6	15	0	0	28	68	12	29	1	41	100
11510 White fasciated..	27	28	31	32	22	23	15	16	49	51	46	48	1	96	100
Total fasciated...	49	36	43	31	28	20	15	11	77	56	58	42	2	137	100
11410 White non-fasc....	0	0	26	84	1	3	4	13	1	3	30	97	0	31	100

*Decayed.

This table sufficiently analyzes the results obtained to obviate the necessity of a detailed description. It does not,however, bring out the degree of fasciation shown by the various ears. In the majority of cases the fasciation was not as pronounced as that of the parents, though in several instances a bifurcation of the ear could be noted, in one case the two tips being almost three inches apart. In other words, the average of the offspring shows the abnormality to a lesser degree than do the parents, though among the descendants may be some which equal or even surpass them. The table shows that even when the non-fasciated compound ears are left out of consideration, the conclusion is reached that fasciation may be inherited by a large percentage of the offspring, in one case 75%, and in another almost that proportion,of the plants bearing fasciated ears. If the compound ears are to be considered as fasciated this number would be considerably increased. So high a percentage is not obtained when fasciation is considered by ear, showing that the fasciation does not always extend to every ear of the plant. At the same time a comparison of the results obtained from No. 11410, a non-fasciated ear, and those from No. 11310 and No. 11510, both fasciated ears, show that fasciation is not a matter of mere accident but one of inheritance and subject to the same laws as are other characters.

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*Lopriore, G. I caratteri anatomici delle radici nastriformi. 1902.

†Sorauer, P. Handbuch der Pflanzenkrankheiten, 1: 334. 1906.

University of Michigan.

A RADIO-ATMOMETER FOR COMPARING LIGHT INTENSITIES.

BURTON EDWARD LIVINGSTON

In attempting to measure and compare the external conditions which influence the behavior of plants there has been brought out a striking relation between the plant population of certain habitats and the evaporating power of the air, the latter being measured and automatically summed by the porous cup atmometer. * But the rate of water loss from plants is usually more affected by sunshine than is the corresponding rate from the porous cup, so that the instrument, as heretofore arranged, fails to give a true measure of all the factors that tend to remove water from the aerial parts. The same is true of the rate of evaporation from the soil surface, which is usually greatly increased by sunshine.

The foliage of ordinary plants, as well as the soil surface, absorb a considerable amount of radiant energy, thereby tending to rise in temperature, and if water be present in the substance of these surfaces (as it always is in living leaves, etc.) a goodly portion of the absorbed energy becomes latent in transforming the liquid water to its vapor. Thus the rate of water loss is

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*The literature of the instrument and its use is given to date in *Plant World* 13: 112-118 1910. Later has appeared: Brown, W. H., Evaporation and Plant Habitats in Jamaica. *Plant World*, 13: 268-72. 1910.

increased by the energy absorbed. The white porous clay cup absorbs comparatively little radiation and is thus not affected as profoundly as are the plants and the soil. It seemed desirable, therefore, that an intsrument be devised that should absorb as much as possible of the radiant energy of sunshine and should integrate the effects of this absorbed energy in a manner as satisfactory as that in which the porous cup atmometer sums the effects of the evaporating power of the air. An attempt in this direction, lasting over several years, has met with some degree of success, and it is to lay the resulting instrument before physiologists, agriculturists, and ecologists that this paper appears. *

The radio-atmometer is merely the common form of porous clay atmometer with the clay surface so modified that it absorbs a considerable amount of the radiant energy falling upon it. Two forms of cup are available, one made of colored clay, the other coated with lamp-black. The former possesses a dark brown color and has the advantage of retaining its color in spite of rain, the latter is dead black. These cups are set up in the ordinary manner, excepting that the position of the cups with reference to the direction of the incident light and heat must be such that the angle of incidence will not vary throughout the period of observation. If this angle be allowed to change there will be introduced errors in the form of apparent variations in the light intensity and the correction for such errors would be laborious and uncertain. The difficulty is readily avoided if we simply so place the cylindrical cup that the sunshine falls upon it perpendicularly to its long axis at all times of the day, the source of radiation thus virtually rotating about the cylinder in a plane perpendicular to its long axis. The position of the cup thus depends upon the latitude and season. It may pe placed empirically at noon by seeing that it receives the sun's rays perpendicularly, and at the same time that its axis lies in the same vertical plane as the sun. For the northern hemisphere its tip will point more or less to the northward of the zenith. It will need to be readjusted every few days. Of

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*This instrument and its readings are compared to the plant and its rates of water loss, under varied conditions of solar radiation, in an article about to appear in the *Botanical Gazette*. Other instruments also are there considered.

course the angle at which the instrument is to be placed may be determined beforehand by reference to the almanac. It has been found convenient to mount the cups on a flexible tube of lead or copper, though a rubber section inserted between two glass tubes is as satisfactory, providing a proper support for the cup be arranged.

To blacken the cups, ordinary lamp-black is clarified by boiling in distilled water, cooling and decanting, and repeating the process several times. The carbon paste thus obtained may be diluted with distilled water and applied to the cup (*after* the latter is filled and placed in operation) by means of a small brush. A little practice renders the operation easy.

The blackened cup often, though not always, shows a somewhat greater sensitiveness to sunlight than the brown one. Whether this depends upon the *quality* of the light or on some other factor has not been investigated as yet. To have the results comparable, the same form of cup must of course be used throughout any series of observations.

The dark cups function as does the white one, to integrate the effects of the evaporating power of the air, and they add to these the effects of their more complete absorption of radiant energy. A dark cup in darkness or very weak light operates just as does a white one, while in strong light, especially in full sunshine,the difference between the readings is very marked.

Since the radio-atmometer, as so far constructed, sums the effects of absorbed radiant energy only in so far as these effects are in the direction of heating the surface of the instrument (that is, only in a photo-thermal way), the readings obtained therewith bear no necessarily direct relation to the light conditions as these determine the photosynthetic process of plants, which is photo-chemical in its nature. According to the researches of Blackman and Matthaei, * however, we may consider that temperature is more important for photosynthesis than is light intensity, providing of course that there *is* a considerable amount of light, and our instrument takes account of temperature as this would influence plant leaves. At any rate, we are able to compare the varying intensities of sunlight for different times, places, etc. with reference to their influence on *transpiration*. It need hardly be added that the radio-atmometer fails to take account of such secondary effects of light as stomatal movements, wilting and the like, which must be studied by different means.

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*Blackman, F. F. and Matthaei, G. L. C., Phil. Trans. Roy. Soc. Lond. Ser. B, Vol. 197. 1904

The instrument here described is, then, a physical apparatus which embodies some of the properties of plant foliage, being affected in much the same manner as are plants by the two aerial factors, evaporating power of the air and intensity of radiation. Inasmuch as it adds photo-thermal effects to those of the evaporating power of the air, the new instrument is to be regarded as a better one for the study of these alterations in rate of transpiration which have been supposed to be due to purposeful "regulation," than is the ordinary white atmometer. Of course the water loss from different plant forms, and even from different individuals, is not affected to the same degree by conditions of the surroundings, and we need not expect to find the sunshine influence to be the same on all plants as it is on the dark cup. Some plants exhibit a greater sensitiveness to variations in solar intensity than do the cups, others are less sensitive and others approximatelyequal one or the other form of cup in their sensitiveness. We have here not only a means for comparing radiation intensities at different times and places, but also a method by which it should be comparatively easy to study the relative sensitiveness of different plant forms to the same variations in illumination. Such comparisons may furnish a much-needed ballast of quantitative data to the discussion of xerophily and the like.

The Johns Hopkins University.

BOOKS AND CURRENT LITERATURE.

A CALIFORNIA SYLVA.—It is only a year ago that Jepson gave us his "Trees of California," a manual adapted to popular use, and he now crowns his studies in forestry with a noble quarto * worthy of a place on the shelf by the side of Sargent's great Sylva. The excellent mechanical execution of the volume is a credit to the Press of the University of California, and the vast stores of information it contains are not only of the highest scientific value, but are presented in a style so interesting and so perspicuous as to make it a most readable book. The plates are in part reproductions of photographs, mostly taken by the author, and include a series illustrating the effects of wind in modifying tree forms, which is of unusual interest. Other plates are from drawings of uniform excellence. Two maps show the locations respectively of the northern and the southern groves of Big Trees, while the third, of the whole state, is designed with reference to the physical features which are of importance in influencing plant distribution.

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*Jepson, Willis Linn, The Silva of California. Mem. Univ. Cal. Vol 24to, pp 480, pls. 85, maps 3, text figs 10. Berkeley, The University Press. ($10.00s.

The author defines the leading object of this memoir to be the presentation of what is now known concerning the taxonomy and the distribution, both geographical and ecological, of the trees of the state. In addition, he discusses the biology, the habits, the uses and the history of all but the less important species. The systematic part of the work is preceded by chapters on the physiographical distribution and the dendrological characteristics of the California trees. He divides the state into five forest provinces: The Sacramento and San Joaquin valleys, the South Coast Ranges, the North Coast Ranges, (the last two divided by San Francisco Bay), the Sierra Nevada, and Southern California. The forest features of each of these provinces are fully described, and referred to the physical conformations and other causes to which they are due. Their relation to Merriam's life zones is also considered, and a "census table" is given showing the distribution of each species in the five forest provinces. In this connection it is interesting to note that the Southern California province, a region less adapted than any of the others to forest growth, is credited with 57 species, out of a total for the state of 92, only two less than occur in the North Coast province, which has naturally the largest number of all; and that all of the five leguminous trees of the state are restricted to the deserts. The "typically Californian" species are 49 in number, and 18 are strictly peculiar to the state. Only two trees, the Aspen and the Black Willow, are common to California and to the eastern states.

Under the head of Arboreal Characteristics the author treats of leaf variation, regeneration and seed production, wind influences, nanism and other topics. A table is given showing the ages attained by the more important trees, and another giving the diameters and ages of sixteen Big Trees. An examination of this table proves that size and age are not coordinate, for the largest tree, which had a diameter of 24 feet, 2 inches, was only 1,346 years old, while the oldest, with 2,177 annual rings, was only 15 feet, 4 inches in diameter. Much greater ages have been ascirbed to the Big Trees, but Jepson is of the opinion that none are more than 2,500 years old.

The systematic part of the Sylva occupies 220 pages. The descriptions are conscise and clear, and good keys are supplied for the guidance of the student. A full synonomy is not attempted, but each species is supplied with references to the more pertinent literature. The extensive field studies of the author have served him well in giving accuracy to the delimitation of ranges, and in supplying a fund of varied information. It is with no little satisfaction that we record this latest evidence of the activity of the botantiss of the University of California, who have contributed so ably in recent years to the elucidation of the flora of California.—S. B. PARISH.

ATLANTIC PHYTOPLANTLON.—Stuwe reports * on plankton material collected from the Gulf Stream, the Canary Current, the North Equatorial Current, the Guinea Current, the South Equatorial Current, and the Sargasso Sea, in all of which records were made of locality, time, temperature of air and water, depth and character of collection. At the latitude of Brest, diatoms were the chief component, and from thence to the Azores ocean plankton, chiefly *Ceratium*, preponderated. In the Canary Current to the Cape Verde Islands a variety of forms prevailed in which diatoms were again prominent. In the North Equatorial stream *Trichodesmium* was the chief form, but with it Peridineae occurred. In the Guinea Current the flora was meager. *Trichodesmium* preponderated in the South Equatorial Current, and in the Sargossa Sea, *Ceratium*. As regards vertical distribution, diatoms, and to some extent Peridineae, occur at the surface when the water is cold. when it is warmer the latter are more numerous, but they fall behind in warm regions where *Trichodesmium* prevails. Quantitatively the Canary Islands and the North Equatorial Current surpass the Sargasso Sea and the branches of the Gulf Stream.—V. M. SPALDING.

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*Stuwe W., Phytoplankton aus dem Nord-Atlantik. Engler's Bot. Jahrb. XLIII heft 4 225 302, with maps. 1909.

DISTRIBUTION OF HIERACIUM.—Samuellson has recently discussed * the forms of the *Acroleucum* group of the genus *Hieracium*, five in number, which occur in southeast Norway and Sweden. The several forms occupy areas not distinctly separate, and the group can not be broken up into smaller groups of related forms. Intermediate varieties do not occur even when two forms grow close together in the some habitat, and each form exhibits a manifest "center of distribution" where it is most numerously represented. The recent development of the form is, according to the author the most important cause of the facts of distribution recorded. Their areas of distribution are not climatic areas. There are, however, various other forms of *Hieracium* the areas of which are determined by climatic factors. It appears probable that most species of *Hieracium* have arisen by mutation.—V. M. SPALDING.

NOTES AND COMMENT.

The first number of volume I of *Phytopathology*, the official organ of the American Phytopathological Society, has been received. It is published bi-monthly for the society at Ithaca, New York, under the joint editorship of L. R. Jones, C. L. Shear, and H. H. Whetzel, with a list of associate editors whose names are well known in the annals of plant pathology as it has developed in America. It is well illustrated with half-tone plates and zinc etchings, the press work is excellent, and the list of contributors a sufficient guaranty of the high character, both scientific and literary, of the new journal. The subscription price is $3.00 per year, subscriptions to be sent to Donald Reddick, Business Manager, Ithaca, N. Y.

Among the several papers which appear in this first issue is one on "Crown Gall of Plants," by Erwin F. Smith. The results recorded are the outcome of six years' work in the Bureau of Plant Industry on the part of the writer, with whom we are associated Dr. C. O. Townsend, Miss Nellie A. Brown, and Miss Alice E. Haskins. The disease is conclusively shown to be due to bacteria, "not to fungi, not to myxoymcetes, not to mites, not to frosts, not to disturbances in nutrition." Artificial cross innoculation has been successfully performed on a great variety of plants belonging to such widely separated families as Compositae and Salicaceae. The hope expressed by the writer "that in these plant tumors, now so easily producable by a definite microorganism, we possess means of determining the cause of cell division and possibly of shedding some light on the origin of certain malignant animals tumor," is one that will be shared by all who grasp the far-reaching importance of such an outcome.

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*Samuelsson G., Uber die Verbreitung einiger endemischer Pflanzen. Arkiv fur Botanik IX, 12-28, 7 figs. 1910.

Correlation of the results and generalizations in two contiguous sciences is a matter of great importance. When accomplished in the proper manner, it greatly broadens the usefulness of knowledge in both lines. When a scientist seeks to project the principles of his own specialty into a related branch, however, many pitfalls await him. He is more than likely to accept the fading generalizations and hackneyed statements of the sister science as the measure of its progress.

This is well exemplified in the address, "A Universal Law," given by Professor Bancroft before the American Chemical Society at Minneapolis recently (*Science*, Vol. 33, p. 179

Professor Bancroft says: "The view of the biologists seems to be that each generation always varies spontaneously from the preceding one to a greater or lesser extent, and that these variations are reproduced more or less completely in the succeeding generation. By the survival of the fittest we eventually get a race which is better adapted to the local conditions than the one from which we started."

This version of unmodified natural selection as first formulated by Darwin does not represent the prevailing views of the subject among botanists and is not held by any modern worker—certainly not by any experimentalist.

In the next paragraph, Professor Bancroft, as the result of the adduction of principles formulated in chemistry, says: "The view that I have outlined is that the external conditions tend to produce such changes in the organism that the next generation varies in such a way as to be more adapted to local conditions. By the survival of the fittest and by the continued action of the external conditions, we eventually get a race which is better adapted to the local conditions than the one from which we started."

This statement embodies the baldest Lamarckianism, which has absolutely nothing to support it in the way of actual experience. Furthermore, a brief acquaintance with the activities of workers in evolutionary science, particularly among botanists, would show Professor Bancroft that the problems of the relation of qualities of organisms and external conditions occupy the foremost place in the amount of attention received at the present time—with some definite results available.

Professor Bancroft's reckless scissoring from various publications, with no attempt to weigh their relative value, does not strengthen the treatment given the subject. Chemistry does not aid natural history by the criticism of outworn generalizations and discarded results of biological science.

In all the numbers of *Torreya* for 1910, possibly the most valuable series of articles are those by Professor W. F. Ganong on "Botanical Education in America." which is none the less helpful because of the previous presentation of its essentials elsewhere. One can not help being glad that the author has given himself so unreservedly to the great work of botanical education, and that his thought has been presented with such clearness, force and consistency. Those who are engaged in teaching botany—and upon them depends in a large measure the future of American botany—will hardly be able to find, in our own or in foreign literature, any more perfect examples of scientific exactness combined with a true phliosophical spirit than are found in the pedagogical writings of Professor Ganong.

The American Fern Journal for January, 1911, (Volume 1, No. 3) has been received and gives promise of filling a useful place in botanical literature. Subscriptions ($1.00) including membership in the American Fern Society for one year, should be sent to Mr. H. G. Rugg, Hanover, N. H.

Volume 14 Number 5

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

MAY, 1911

A SKETCH OF THE HISTORY OF PLANT MORPHOLOGY IN AMERICA.

DOUGLAS HOUGHTON CAMPBELL.

The history of botany in the United States previous to the middle seventies of the last century was almost exclusively a history of taxonomy of the vascular plants. It is true that in some of the text-books a certain amount of morphological work was included, but this was of a very general character. The prevailing ideas of morphology, especially those dealing with the homologies of the floral parts, were quite uninfluenced by the discoveries of the European morphologists whose work has since made a revolution in the fundamental principles of morphology. Prior to 1870 we may say that practically no serious morphological work had been done by American botanists.

That the work of this earlier period should be mainly taxonomic is not to be wondered at since the rich and interesting flora of the United States offered a most tempting field to the systematist, and, moreover, none of our botanists had been trained in the European laboratories, whence there had just begun to penetrate to the outer world the results of the labors of the brilliant workers in morphology and physiology who, in Germany especially, made the middle decades of the nineteenth century the most notable period in the whole history of the science.

Probably the name of Hofmeister will stand first in the distinguished line of morphologists who, contemporary with

Darwin, but working quite independently, effected a veritable revolution in the botanical world. Hofmeister's principal work, his studies on the comparative morphology of the Archegoniates and Gymnosperms, which practically broke down the old barriers separating "Cryptogams" and "Phanerogams," was translated into English in 1862, and thus made accessible to students in England and America. This work, important as it was, seems to have had little immediate influence upon the trend of botanical work either in England or America.

Perhaps even more influential, especially as a teacher, was the great Sachs, whose famous text-book forms an epoch in the history of botany, and probably did more than any other single volume to advance the teaching of the science ,not only in Germany, but in England and America as well. In the Sachs' text-book there was presented for the first time an adequate treatment of the vegetable kingdom in its entirety, and although some of his conclusions as to the relationships of certain groups of plants are no longer held, his classification was an immense advance upon any that had preceded it, and was a fairly successful attempt, at least, to indicate the genetic relationships existing between the different main divisions of plants.

The history of morphological botany in America may be said to date from about the middle seventies. At that time a number of young botanists returned from Germany to America and inaugurated courses in cryptogamic botany and morphology which gave a great impetus to the study of what may be called the biological side of botany as distinct from the purely taxonomic aspect of the science.

The establishment of a department of cryptogamic botany at Harvard was an event of no small importance, and the long series of important contributions to the morphology of the lower cryptogams which has ever since emanated from the cryptogamic laboratory of Harvard University bears witness to the high standards maintained at our oldest and most important school of botany. About the same time that the department of cryptogamic botany was organized at Harvard, Professor Harrington of the University of Michigan, offered a course in botany which was largely of a morphological nature and was the beginning of the large and well organized department of botany developed by his successors. In those early days there were very few professorships of botany, and much credit is due the pioneers who, with inadequate facilities and small pay, did so much to lay the foundations of the well-equipped departments of botany which now form a part of every university of any pretensions.

When about 1880, an enthusiastic group of young English botanists, all of whom afterwards became distinguished, studied in Germany under Sachs and De Bary, and, on returning to England, put into admirable English dress the famous text-books of those German masters, they did a piece of work which was far-reaching in its effects. Shortly after the appearance of the translation of the great Sachs' text-book Professor Bessey offered to the American student his excellent text, largely based upon this, and there appeared soon after a number of other books some of which were strictly laboratory manuals. All of these text-books strongly emphasized the morphological aspect of the subject, and everywhere the students were hard at work tracing life histories and studying comparative morphology.

The results of this activity were soon evident in an ever increasing number of publications of a morphological character. Moreover, during the ten years from 1885 to 1895, a large number of American students went to Germany for study, where many of them came under the influence of the great morphologist, Strasburger, who probably was the most potent factor in directing the work of the morphological students at that period. This was especially seen in the great number of cytological papers produced in his laboratory, or as a result of his writings. Among the most active American workers in this field may be mentioned Atkinson, Chamberlain, Davis, Harper, Lawson, Mottier, Schaffner and Shaw.

It was during this period that the interest in cytological problems was probably at its height. This was due in part to the introduction among botanists of the more exact methods of fixing and staining, in which the zoologists had been rather ahead of the botanists. It was during this period also, that the microtome came into general use as an adjunct to botanical research. The use of the microtome, making possible accurate series of sections, marked a great advance in the study of plant morphology. This was especially the case in embryological investigations, where free-hand sectioning had been practically universal among botanists up to about 1885. The adoption of the microtome in the botanical laboratories of America soon resulted in the solution of many very difficult problems, such as the development of the prothallium of the heterosporous Pteridophytes and the minute details in the history of the embryo-sac and embryo of the seed-plants.

The study of the gametophyte in the seed-plants has been a favorite theme with American botanists. In this province the influence of the strong botanical department of the University of Chicago has been very great. The long series of papers on both Gymnosperms and Angiosperms, written by members of the staff or by students working in the Hull Botanical Laboratory, and many other papers prepared by students trained in Chicago, make one of the most important contributions to morphology that this country has produced.

First in importance of the work of the Chicago botanists has been the series of investigations upon the Gymnosperms, especially the papers dealing with the Cycads. The striking discovery of spermatozoids in *Cycas* and *Ginkgo* by the Japanese botanists, Ikeno, and Hirase and those of *Zamia*, discovered by Webber in America, aroused renewed interest in the development of the Gymnosperms, and this was especially the case in Chicago where the results of many years of special investigations were finally embodied in the admirable treatise on the Gymnosperms recently published by Professors Coulter and Chamberlain. Other investigators who have interested themselves in the morphological study of the Gymnosperms are Coker, Miss Ferguson, Jeffrey, Lawson, Penhallow, Shaw, and Webber.

The number of investigations on the development of the Angiosperms, especially those dealing with the structures of the embryo-sac, has been very large. Particular interest has been shown in the question of the homologies of the embryo-sac structures, and a search for forms which connect the prevailing type with more primitive ones. Of the many contributors to this important subject, the following investigators may be referred to: Atkinson, Coulter, Campbell, Cannon, Johnson, Mottier, and Schaffner.

A phase of morphology that has been more diligently pursued in England than in America, due largely to its bearing on the study of fossil plants, is the vascular anatomy of the higher plants, especially that of the Gymnosperms and Pteridophytes. The best known exponent of this phase of morphology in America is Professor E. C. Jeffrey.

The morphology of the archegoniate plants, the mosses and ferns, has received its share of attention in America during the past twenty-five years. Among those who have been active in this department may be mentioned Atkinson, Barnes, Campbell, Evans, Howe, Jeffrey, Johnson, Lyon, and Underwood.

The morphological work upon Algæ has been less extensive perhaps than that upon the higher cryptogams and seed-plants, but a good many valuable contributions have been made by American botanists to the morphology of this group. Some of those who have made important additions to our knowledge of the morphology of these plants are Farlow, Davis, Howe, Kofoid, Moore, Osterhout, Saunders, and Setchell.

The Fungi, comprising as they do the largest number of plants outside of the Angiosperms, have naturally received a good deal of attention from botanists, but this has been for the most part rather from the taxonomic and economic side than from the side of pure morphology. Nevertheless, some notable morphological work on the Fungi has been done by American botanists. Farlow's early papers on Fungi were among the first American contributions to the morphology of the cryptogams, and among the notable work of more recent date must be mentioned the very important contributions of Harper and Thaxter.

Of the more recent phases of morphological work, that of experimental morphology must be mentioned, although this might be considered to be rather a phase of physiology than of pure morphology. Some of the most important botanical work done under the auspices of the Carnegie Institution of Washington comes under this head, and the work of MacDougal and his colleagues perhaps represents the most important contribution to this department of botany that has been done in America

We have, finally, to consider the suggestive lines of work inspired by De Vries' mutation theory, and the re-discovery of Mendel's work. It is not necessary to call attention to the great influence which both the Mutation theory and the Mendelian law of heredity have had upon the work both of botanists and zoologists during the past decade. It must be admitted, however, that as yet the results obtained by the numerous students of this latest fashion in biological investigation have hardly been commensurate with the expectations of the earlier disciples of De Vries. Nevertheless, the careful study of variation, stimulated by these important theories, has been very useful in reducing to definite form many phenomena long recognized in a vague way, but never before clearly formulated.

The tendency of any striking new theory to draw away from the older and perhaps more humdrum lines of work a large number of students is a familiar phenomenon, and perhaps some lines of morphological work have suffered of late from the desertion of older workers, and the natural tendency of the younger students to attack the latest problems presented to them. It may be safely assumed, however, that there is plenty of work still to be done along the lines of the older morphology, and the very creditable showing of the work of American morphologists during the past twenty-five years makes one hopeful that in the years to come the students of morphology in America will not fall behind their record of the past generation.

Stanford University.

STUDIES IN SOIL PHYSICS, III.

SOIL WATER AND THE PLANT.*

E. E. FREE.

The purely inorganic aspects of the occurrence of water in the soil and its movements therein were discussed in the previous paper of this series. It remains to notice the more vital matter of the relation of this soil water to the plant by which it is used and for the life of which it is essential. Of the conclusions of the previous papers it is necessary only to recall that in normal soils under usual conditions most of the water exists in the form of films around the soil grains and in the capillary spaces. It is this film water which forms the source of supply for most of the useful plants. The cases in which the roots of a crop actually reach the ground water are comparatively rare. Nearly always this ground water must be raised by capillary action before it can be useful to the plant.

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The Water Equation of the Plant. Water is, of course, an important material of plant food but in all ordinary land plants the total water used is far in excess of that required for mere nutrition. Water passes not only into but through the plant—is both absorbed by the roots and "transpired" by the leaves. We know fully neither the mechanism of absorption nor the mechanism of transpiration and we know very little of the mechanism of transfer from roots to leaves—the much discussed problem of the "ascent of sap". But these gaps in our knowledge, however regrettable, matter little to the present discussion. We need to know only that there *is* a water stream through the plant—and here is the important point—that its rate of flow may be limited or restricted at two points: the point of exit and the point of entry. The water equation of the plant is determined by two rates, the rate of transpiration and the rate of absorption.

Now these rates are not necessarily nor directly related. They may vary almost independently and either may be larger than the other. Obviously when transpiration is greater than absorption the plant is losing water and drying, while, when absorption is greater than transpiration it is gaining water and swelling. Obviously, also, neither of these unbalanced conditions can long endure if there is to continue to be a plant. In one case it will dry up and die and in the other it will swell up and burst. Over extended periods of time, then, the summation of absorption must equal the summation of transpiration, plus what water has actually been built into plant tissue. The plant might be compared to a water reservoir, into which water is running and from which it is being drawn. If the rate of exit be greater than the rate of entry the reservoir will run dry; if it be less it will run over. Either condition may be assumed fatal to the proper functioning of the system. To be useful the reservoir must be kept filled to a level which must be, if not absolutely constant, at least variable only within definite and relatively narrow limits. Similarily in the plant, transient excesses of transpiration over absorption or vice versa are permissable and harmless, long maintained differences are fatal. *

Since, then, these rates of absorption and transpiration are so important to the life and the health of the plant it is expedient to review a little the factors which control them even though, in the case of transpiration at least, these factors are fairly well known and appreciated. The factors which control the rate of transpiration are partly internal and dependent upon the plant, and partly external and dependent upon its environment. Of the former there are probably two, the mechanism of exposure (including the amount and character of the surface of the internal spaces of the leaf, the character of the cell membranes the nature and number of the stomata, etc.) and the concentration (acting here through its effect on vapor pressure) of dissolved substances in the cell solution from which the evaporation is taking place. The former or mechanical factors are probably pretty nearly constant for any one plant.

The external or environmental factors are the temperature and the humidity of the air and its rate of movement—the wind. All these may be included in the one expression "the evaporating power of the air." This it is which practically controls the transpiration of any given plant. An increase in the concentration of the cell solution does, it is true, lower the rate of evaporation (here transpiration) but this lowering is small and seldom comparable with changes produced by variations in the evaporating power of the air. If this evaporating power be greater than that to which the plant is adapted or to which it has been accustomed the plant dies.

The rate of absorption is also controlled by factors which may be divided into those determined by the plant itself and

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*In actual fact these is usually a difference between transpiration and absorption and it is usualy diurnaly reversed. The plant looses water during the day and gains it at night. There are some few plants also which have considerable capacity for storing water and are able to withstand long periods of excess transpiration by drawing on water which had been stored during previous periods of excess absorption.

those determined by its environment. The former are again a mechanism—the mechanism of root absorption—and a factor depending upon the concentration of the solution in the root cells. This concentration factor is here osmotic in nature and depends upon the fact that water will pass through a semipermeable membrane, such as the cell wall, from a solution of lower osmotic pressure to one of higher. If, then, the cell solutions of the root have a higher osmotic pressure (which means, in most cases, higher concentration) than the soil solution, water passes from soil to root and, other things equal, the rate of passage varies directly with the difference in concentration, though perhaps not in exact proportionality thereto. The urging force which causes water to move into the plant at all is this same difference in osmotic pressure, and the greater the difference the greater the force.* The mechanism of root absorption, (the surface exposed, the permeability of the membrane, etc.,)is, like the mechanism of transpiration, nearly constant for any given plant and, like it also, is of practical importance only as setting an upper limit. Not more than so much water can pass into a given plant even under the best soil conditions, and if the transpiration exceed this amount the plant will die though its roots be bathed in unlimited water.

The external factor in absorption is the capillary pressure ‡ of the water in the soil. For any given soil against any given plant there is probably a certain content of soil water below which that plant is unable to further extract moisture. The pressure under which the water is held in the capillary spaces and in the films about the soil grains is then greater than the difference of osmotic pressures urging the water into the root. But this limiting water content even if it be a physical reality|| is quite low and it is seldom that useful soils are so dry as this throughout their whole mass. The importance of the phe-

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*It may seem that this theory of the action of osmotic forces on root absorption is inconsistent with the fact that dissolved food materials enter the plant through its roots. When the cell solution is more concentrated than the soil solution nothing but water can enter, and when it is less so nothing at all can enter. To the outline theory, as above stated, this objection is perfectly valid. But not all of the osmotic theory has been stated. The considerations of partial and selective permeability and the effects of the presence of many different salts in the solutions have not been discussed nor will they be. The theory as stated applies accurately enough to the water stream, and with the more precise matters of nutrition and total absorption we are not here concerned.

‡See the previous paper of this series, Plant World, 14:60, 1911. As there pointed out hygroscoptic forces are not practically important in ordinary moist soils.

|| This matter is more fully discussed below

nomena lies elsewhere. It is apparent that the plant roots can be actually in contact with only a very small part of the soil at one time, and, as water absorption goes on, this soil which is touched by the roots would be very soon dried out were it not for one thing. More water is immediately supplied from other parts of the soil by capillary movement. * If the rate of this movement be low, the rate of water absorption must necessarily be low also even though there be plenty of water in the soil as a whole. The dearth of water is in the contiguous soil only. It is not that there is too little water but that it is too slowly supplied. This is often the case when plants wilt and die from sudden hot winds. The rate of transpiration suddenly jumps up and the plant is dried out and killed before the saving water can move through the soil and reach the roots.

It will be noticed that factors depending upon the concentration of the cell solution appear in both sides of the equation—as controllers both of transpiration and of absorption. This is why it was necessary above to say that the rates of absorption and of transpiration could vary *almost* independently. The concentration relations are the reason for the "almost." It will be remembered that transpiration decreases with increase in sap concentration, while under the same conditions absorption increases. It is apparent, therefore, that if some means exist by which the sap concentration at leaves and roots is kept substantially the same, there really is some relation between transpiration and absorption. To be more precise, there is an influence of the water content of the plant on both transpiration and absorption, as well as of them on it. If the plant becomes too dry the concentration of the cell solution increases, and, in turn, transpiration decreases and absorption increases; both of which changes tend to remove the condition which gave them rise. But this process of natural regulation is efficacious between narrow limits only. It maintains the balance of transpiration and absorption under normal conditions—prevents a dessication or a drowning due to any possible "mistake" of the transpiring or absorbing mechanism. It is competent also to care for the constantly occurring slight variations in external conditions, which are the evaporating power of the air and the supply of moisture through the soil.

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*As discussed in the previous paper.

It must be remembered, of course, that this concentration factor has nothing to do with the total amount of water transpired or absorbed, or with the draft of transpiration and the plant upon the water of the soil. So long as water be freely supplied to the plant roots and freely absorbed by them the sap concentration will be the same whether the yearly transpiration rate be one ton or ten tons. It is only when the soil water begins to run low or the rate of transpiration grows high enough to tax the absorbing and transmitting mechanism, that the increase of sap concentration begins to operate and restrict the outgo.

In summary, we may say that the rate of transpiration is controlled by the mechanism of exposure, the concentration of the cell solution and the evaporating power of the air, and that the rate of absorption is controlled by the mechanism of contact, the concentration of the cell solution and the supply of capillary water by the soil. The upper limits of transpiration and absorption are fixed by the mechanisms concerned,—by the mechanical construction of the plant; the equality of transpiration and absorption is maintained, under normal conditions, by the concentration of the cell sap; and the actual amounts of transpiration and absorption are determined primarily by the evaporating power of the air and secondarily by the rate of capillary supply from the soil. These latter factors also determine whether or not the plant can be kept within that range of conditions, which is called normal, and between the limits of which alone is change of sap concentration able to maintain the proper balance of outgo and income. The danger of the fatal disturbance of this balance is almost entirely in one direction only. Plants frequently suffer from a deficiency of water but very seldom from an excess. Too much transpiration or too little absorption are the ever present dangers; there need be no fear of too little transpiration or too much absorption. To summarize again, a plant may die of drouth either (1) because the soil water has given out; (2) because the transpiration rate is greater than the maximum rate of absorption which the absorbing mechanism will permit;[*] or (3) because the evaporating power of the air is persistently high enough to require a transpiration rate greater than the maximum rate of capillary movement of soil water to the roots.

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[*] For an instance of this see Livingston, Plant World 10: 269, 1907.

All this concerns extreme conditions,—conditions which have become "abnormal" and under which life itself is not long possible. From the practical viewpoint the more normal, less extreme, conditions are of far greater importance. We are less interested in why plants die than in how (or how efficiently) they live. Under these normal conditions, which we may define as the conditions adapted to the particular plant under consideration, the total absorption will be equal to, and determined by, the amount of transpiration, the latter quantity being fixed by the variable factor of the evaporating power of the air and the relatively constant factor of the mechanism of transpiration. Changes in the evaporating power of the air will be followed by corresponding changes both in transpiration and in absorption and the necessary balance of the two will be maintained without change in the internal conditions of the plant. Suppose, however, that the evaporating power of the air increases to a point at which the transpiration it necessitates can just be balanced and no more by the supply of soil water. Suppose, then, the evaporating power of the air to increase a little more. Transpiration will increase but absorption can not because water can not be supplied any faster. Obviously the plant will lose water. But this loss of water causes an increase of sap concentration, this causes a reduction of transpiration, and equilibrium is restored, the only difference being that the cell solution is a little more concentrated than it was. Unfortunately, however, this increase of sap concentration is (for some reason not fully known) unfavorable to the plant. Life may go on but rapid growth does not and this is obviously a matter of extreme importance to practical agriculture. Maximum yields can be obtained only when the possible rate of supply of soil moisture is sufficient to balance any transpiration which the climatic situation is likely to require.

The Wilting Point. The ideas elaborated in the preceding section can be applied with profit to a few of the conceptions current in the borderland of plant physiology and soil physics. Let us take first the so-called "wilting point," usually defined as the water content at which a given plant will wilt permanently in a given soil. It ought to be obvious that this quantity will depend primarily, not on the plant nor on the soil, but on the evaporating power of the air. But strange to say this apparently obvious fact has been either overlooked or disregarded by nine-tenths of the workers who have made wilting point determinations.[*] The temperature and humidity are almost never stated and in most cases they were apparently neither measured nor controlled. Another matter almost always neglected in determinations of the wilting point is the *rate* of movement of water through the soil. The plant may wilt, not because of a lack of water, but because the water is unable to move through the soil and to the plant as rapidly as it is being removed by transpiration. Nor will this possible error be removed by determining (as is usually done) whether or not the wilting be permanent. For permanent wilting and death will result from any continued excess of transpiration over absorption, whether the deficiency of the latter be due to total lack of water or to a too slow supply.

To have any meaning either for plant physiologist or soil physicist the wilting point must be determined with reference to the evaporating power of the air. Even so determined, local and occasional experiments are of little value and general experiments, though potentially very useful, would be exceedingly tedious and even more costly. If experiments are to be made in this field they had better be upon the rate of transpiration which is fatal with full water supply, upon the minimum rates of absorption and transpiration which are possible, or, best of all, upon the amount of water which will be transpired (and hence extracted from the soil) by a given plant in air of a given evaporating power.

Available and Non-Available Water. The concept of non-available water is closely related to that of the wilting point. Non-available water is usually defined as that percent of water which still remains in the soil after the plant has wilted. As so determined (and I am aware of no determinations made otherwise) it is subject to all the errors which affect the determination of the wilting point and which have just been discussed. But further than this there is no real assurance that there is any such thing as non available water. Nine times out of ten a plant dies not because the water in the soil is no longer available but because it is no longer supplied with sufficient rapidity. The matter is really one of rates,—a matter with which pure quantity factors have nothing to do. It is possible of course (and indeed probable, as stated above on page 113) that there is really a point at which the capillary pressure in the soil balances the osmotic urge into the plant, and at which water is actually no longer absorbed. Water below such a content would be really "non-available." As yet, however, the very existence of such a point is unproved and the first experimentation on this phenomenon should be the investigation of its reality.

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[*] There are, of course, a few physiologists who have given full attention to the importance of evaporation in this connection. The papers of B. E. Livingston are notable examples

It must be remembered too that there is a possible non-availability of soil water with which the plant has nothing to do, but which is caused by a breaking of capillary contact between the soil grains immediately in contact with the plant roots and the main body of the soil. This, if it occurs, is a purely physical matter and is physically determinable. The dragging of the plant into the question is neither necessary nor desirable. It has nothing to do with the case.

The Optimum Water Content. It has long been observed that too much water and too little are alike injurious to plants. The most healthful conditions and the best growth are obtained when the soil possesses an intermediate water content the actual value of which varies for different soils and for different plants. This water content is known as the optimum. In the first paper of this series it was noted that for most plants this optimum corresponds to that water content * at which the physical properties of the soil employed show an inversion and at which the soil is in, or in condition to take on, its most favorable physical structure. It may be that this physical factor is alone sufficient to explain the existence of the biologic optimum. Plants may perhaps grow best at this water content simply because at higher or lower contents the physical soil conditions are less favorable. It is more probable, however, that the phenomenon is more complex and depends upon other factors also, and especially upon the water supply and the amount of air space in the soil. The water supply furnishes a cause for decreasing productivity when the water content is too low. There is simply a lack of water. On the other hand the air supply of the roots may possibly be the cause of the trouble when the water content is too high. If the soil be too wet it is not only in poorer physical condition, but many or most of its interspaces are full of water and the plant roots are shut off from the soil air with which they are usually in contact. It is not yet known how necessary this soil air is to the plant but it is probably more or less so, and its exclusion may be a material cause of low productivity. Simply the quantity of water in the soil might therefore produce the observed optimum entirely aside from physical factors. Too little water would be unfavorable because of a two slow supply of needed water; too much water would be unfavorable because of the exclusion of the air. The maximally favorable conditions would be found over the middle range where both water and air were supplied in adequate quantity.

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*Called the "critical moisture content".

We have, then, *two* apparently efficient causes of the observed phenomenon of the optimum, one purely physical, the other partly biological and related to the supply of water and of air. It is probable that the latter factor of water supply and aeration simply determines the *range* within which the optimum must lie, while its exact position within this range is probably determined by the physical soil condition and is always coincident with the critical moisture content whenever that value lies within the required range.

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THE SEEDLING OF *QUERCUS VIRGINIANA*.

ISAAC M. LEWIS.

For our knowledge of the mode of germination and seedling structure of the oaks, we are indebted to the contributions of Sir John Lubbock,[*] Rowlee and Hastings,[‡] and Kerner and Oliver.[||] These writers have described the germination and

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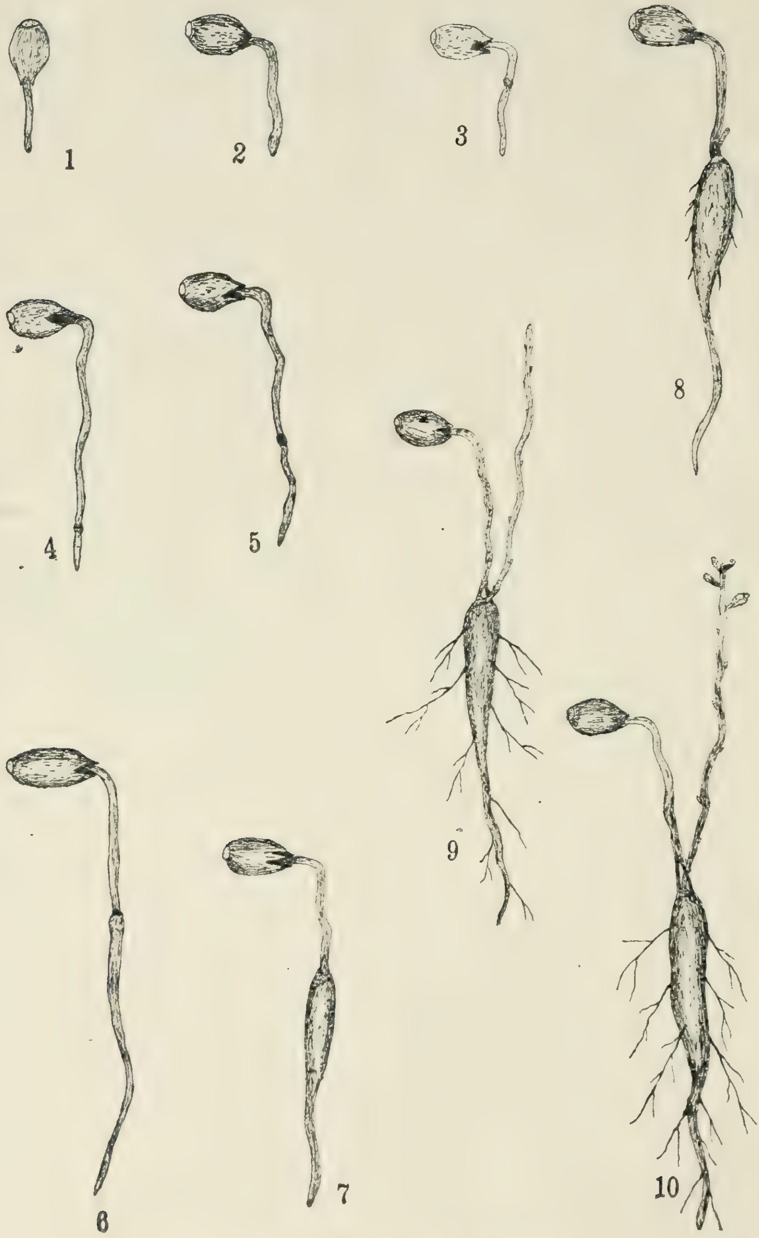
[*] Lubbock, Sir John A Contribution to our Knowledge of Seedlings. Vol. II, 534.

[‡] Rowlee, W. W. and Hastings, George. The Seeds and Seedlings of some Amentiferae; Bot. Gaz. 28: 349. 1898.

[||] Kerner and Oliver. The Natural History of Plants. Vol. I, 607.



LEWIS: SEEDLING OF QUERCUS.

figured young seedlings of several species of the genus including: *Quercus ilex*, *Q. pedunculata*, *Q. velutina*, *Q. macrocarpa*, *Q. platonoides*,and *Q. austriaca*. All of these species behave much alike in germination and there is very little difference to be noticed in the type of seedling produced. It is a well known fact that in certain genera of plants biological variations often occur in regard to the relative development of the primary root, the hypocotyl and the cotyledons. It would not therefore, be surprising if we should find in some of the oaks a departure from the usual type in one or more of these structures.

In all of the oaks germination takes place by the same method. The cotyledons swell at the point where the petioles join them and thus the outer shell is split open and the cotyledons forced apart. The radicle then grows out and the petioles of the cotyledons elongate and carry out the plumule. The primary root in *Q. ilex* and *Q. pedunculata* is "long, woody, flexuose, tapering, dark colored and wiry." The hypocotyl is "woody, subterranean, stout, dark colored, flexuose," more or less distinct from the root. The petioles of the cotyledons are never united into one piece, and their length is about one centimeter. The seedlings of the other species described are very similar to *Q. ilex*.

The seedlings of the *Q. Girginiana* differs from this type in three important particulars: The primary root is very thick and fleshy, closely resembling that of *Hicoria* or *Juglans*. The petioles of the cotyledons are not separate but are united throughout their entire length into one terete structure which often reaches a length of five or six centimeters. The hypocotyl is rudimentary, being only a few millimeters in length.

The acorns of the *Q. Girginiana* germinate immediately after maturity, if conditions are favorable. The petiole is the first structure to elongate perceptably, and no matter in what position the acorn is lying it bends in such a way as to direct the radicle downward. It must therefore be positively geotropic, although it would seem highly probable that the stimulus is perceived by the root tip and transmitted through the radicle to the petioles.* The petiole grows much more rapidly

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*Copeland, E. B., Studies on the Geotropism of Stems. Bot. Gaz. 31: 410-423. 1901.
Schutze, Rud., Ueber das geotropische Verhalten des Hypokotyls und des Kotyledons Jahrb. Wiss. Bot. 48: 377-423. 1910.

than the primary root, and often when it has reached its maximum length the root has not elongated more than one or two centimeters. (fig. 1-5.)

Following the rapid growth of the cotyledonary petiole, the primary root begins its period of elongation. Its growth is also rapid at first but after a length of six or eight centimeters has been reached, proceeds much more slowly and the increase in diameter begins. This growth in length and diameter produces a fleshy structure ten centimeters or more in length and with a maximum diameter of about one centimeter before the plumule begins to grow. There is very little woody tissue in the root, but it consists principally of parenchymatous cells richly filled with starch. The outer layer of cells becomes brown and corky and more or less deeply fissured (figs.7-8.) The starch from the acorn is largely transported down into this subterranean structure and stored within its cells. Later the root increases in diameter by the addition of woody cells and the plumule, which has been carried down by the elongated petiole and has remained dormant, elongates to form the stem. The stored starch is used up in the subsequent growth. In seedlings one or two years old, little starch is to be found in this original storage tissue. The empty parenchymatous cells form the pith of the now greatly enlarged primary root.

The plumule does not begin to develop until after the primary root has about reached the maximum size which it ordinarily attains before the woody thickening begins. It now begins to grow and in so doing separates the petiole into two parts near the point of attachment to the rudimentary hypocotyl, and escapes through the opening. It appears usually about six weeks from the time germination begins, and doubtless under less favorable conditions might be delayed much longer.

The young stem is so situated that it must attain a length of six or eight centimeters before it reaches the surface of the ground. The first leaves to develop are scale-like and number eight or nine. The first green leaves are much more notched and serrate than is characteristic of the adult leaves of the species. (figs. 9-10.)

It will be seen that the petiole of the cotyledons in this species serves as a"sinker" in much the same way as is characteristic of certain monocotyledonous plants, notably *Phoenix dactylifera*. This habit, correlated with the habit of transporting the material from the acorn down to a position of greater safety in the fleshy root,would seem to be a decided advantage to the plant in establishing itself in the semi-arid situations in which it is often found.

University of Texas.

BOOKS AND CURRENT LITERATURE.

THE PRODUCTION OF VEGETABLE SEEDS.—Of the numerous recent contributions to the subject of seed growing one of the most important is a paper * by Dr. W. W. Tracy on The Production of Vegetable Seeds, which has many important features as a record of scientifiic experiment and experience.

A seed is defined as essentially "a plant packed for transportation." Its good appearance as to cleanliness, plumpness and color is a desirable quality, but one that may be quite misleading as to comparative value. In Red Valentine beans, for example, a plump, full, symmetrical bean of a bright red color is apt to go with inferior varietal quality,while a twisted unsymmetrical shape and a dull color are generally indications of a pure stock.

That every grain will under favorable conditions develop into a healthy plant would be regarded by many who have little horticultural experience as the most important of all qualities. But of two lots of seeds in one of which 60 to 75 percent of the grains will develop into plants which are typical of the variety, while the remainder will not germinate at all, and in the other, though every seed is viable, only 10 or 20 percent of them will produce typical plants of the sort, the others developing into a medley of different forms and qualities,the first lot, though only 60 to 70 percent viable, is decidedly the most satisfactory and valuable.

Passing from these and various other interesting considerations of a general nature, the author takes up speeificially the growing of sweet corn for seed, discussing the first influence of location on quality.

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*The Production of Vegetable Seeds. Bur. Plant Ind. Bull. 184, 1910

The qualities of sweetness and tenderness, as well as earliness of maturity,in green corn are influenced by soil and climatic conditions, but there is a difference of opinion as to how far this influence is carried in the seed. The corn packers of Maine insist that green corn grown in the north from northern-grown seed is superior to that which can be produced from seed grown farther south. The Maryland packers insist that they can get not only more but sweeter and more tender corn from seed grown in their own locailty. In both cases the superior results obtained from local grown seed may be accounted for from the fact that seed grown in any locality for a number of generations has been found by experimentation to give better results in that locality than seed of the same stock equally well grown elsewhere.

If we carefully select ears grown from eastern and from western seed which are in exactly the same stage of maturity, chemical analysis fails to detect and constant difference in sugar content. There is, however, a slight, but discernible, difference in the size of chit, or germ, and in a general way the green corn from western seed is slightly coarser in texture and less tender than that from eastern seed. The difference in quality may be accounted for as follows:

The climatic conditions in the western corn-growing sections, especially during the season when corn is earing, are often such as to induce a marvellously rapid development—much more rapid than is usually seen in the east, In the West it is sometimes difficult to find ears of sweet corn green enough to be in prime boiling condition in fields where it was difficult to find ears which were mature enough to be palatable forty-eight to seventy-two hours earlier. Seed grown under such conditions would often transmit the rapid-maturing habit of the plants that produce it. The quality of green corn, particularly as to tenderness and sweetness, is very dependent upon the stage of maturity at which it is cooked, sometimes the growth of only a few hours affecting the discernible sugar content. If the corn in a field from western seed in which the rapid-maturing habit was transmitted was gathered for canning when most of the ears were in prime green-corn condition, some of the ears would be so mature as to lower the average quality, but it would be impracticable to reject such slighlty over mature ears, and the resulting poor quality of the pack would be charged to generally inferior stock rather than to the effect of the few older ears.

The mixture of varities through cross-pollination is one of the most serious obstacles with which the grower has to contend. Corn pollen in abundance has been obtained from the plumage of a blackbird,which must have flown between four and six miles from the last field of corn visited, and doubtless others of the large flock to which the bird belonged carried equal quantities of pollen, more or less of which they must have scattered in the field of seed sweet corn in which they alighted.

Experience shows that neither a distance less than several miles nor any varietal difference can be relied upon as a certain protection against a mixture of pollen, though much can be done to lessen the probability of a mixture. Usually the most practicable way is to plant each lot of seed as far as possible from any other corn,and also to have as much difference as possible in the dates of ripening of the seed corn and of the corn in the nearest field. In sorting before shelling, if kernels of hybrid corn are found in a given ear, it is well to throw out the whole ear rather than to pick out the mixed grain, because crossing does not always change the appearance of the grain the first season, and there is a strong probability that on an ear on which crossed grains are visible there are other crossed grains which show no external sign of mixture.

The directions for growing stock seed are both of practical and theoretical interest and are reproduced in detail.

First formulate a very clear conception of precisely what an ideal plant of the sort to be grown should be, not only as to grain and ear, but as to stalk, husk, silk and tassel, for this is essential to the raising of the best seed of the sort. With this conception in mind, or what is far better, clearly written out and illustreted by photograph, go into a field of the sort at the time the plants are coming into silk, and mark with a string or bit of cloth, or in some way a number of stalks. It is wise to select at least a hundred plants which are as nearly alike and as typical of the sort as can be found.

When the grain is in the dough state, assemble the marked stalks and, after stripping down the husks, very carefully select and tag those in which the ear and the grain are nearest to the ideal. The ears from each of these selected plants should be carefully numbered, dried and stored. The next spring mark out near the center of the largest available field of the sort, a block of 4, 9, or 16 square rods for each of the selected ears, and plant each block with seed from one of the selected plants.

It is wise in making the planting to reserve at least one-fifth of the seed on each ear, not only for replanting, if necessary, but so that reference may be made to the exact character of the parent stock. When the corn is coming into silk carefully go over the blocks and select those in which the plants in stalk, leaf, husk, silk and tassel are most uniformly of the desired character, rejecting the plants which show the greatest variation, even if some of them, as will in all probability be the case, are among the most perfect plants in the field.

When the corn is passing into the dough state go over the selected blocks, and, stripping down the husks, select the blocks in which the ears are most uniformly of the desired varietal character, rejecting, as in the selection of the individual plants, all the ears, no matter how perfect they may be, from the blocks showing the greatest variation. As a rule it will be best to select several blocks in order to the loss in vegetative vigor which in the corn plant, often follows too close breeding.

From the chosen blocks select a number of the most perfect ears, to be tagged, numbered, kept separate, and again planted in separate blocks next season. The balance of the corn from the selected blocks can be gathered and the better ears bulked and used the following season for planting the field in which the seed blocks are to be located.

Working in this way, never losing sight of or changing the ideal varietal characteristics of the sort, always selecting from the most uniform lot, resisting the temptation to use an exceptionally perfect ear found in a variable block, one can have in a few years established strains which will be greatly superior in practical value to most of the seed now used.

The second half of the bulletin is devoted to the growing of garden beans and peas for seed, and includes important suggestions based on experience in the eastern states, in California and elsewhere.—V. M. SPALDING.

VEGETATION OF THE GALAPAGOS ISLANDS.—Stewart accompanied the expedition of the California Academy of Sciences to the Galapagos Islands in 1905, and has written an extended paper* chiefly devoted to listing the flora of the islands. A detailed tabular scheme shows the distribution of the flora among the 20 principal islands of the group from which the author deduces that there is a strong probability that the islands were formerly fused into a smaller group, or perhaps a single island. The number of the species representative of the several genera and families of continental plants is so small that the hypothesis of a former connection of the Galapagos with the mainland does not appear to be valid. A brief description of the vegetation of the islands calls attention to four types occupying successive altitudes in the larger islands. The coasts are fringed with deserts in which the aborescent columnar cactus, *Cereus sclerocarpus*, and some eight other cacti are conspicuous, with species of *Bursera* and *Croton*. A "Transition Region" and a "Moist Region" are described, in which the vegetation approaches the character of tropical rain forest. At altitudes of 2000 to 3000 feet the the forest is replaced by "Grassy Regions" chiefly covered with a species of *Paspalum*. The operation of several climatic factors is touched upon, and the invasion of the recent lavas by vegetation is briefly described. . .—F. S.

NOTES AND COMMENT.

A distinct sense of pleasure is given by every writer on elementary and secondary school work who decries the prevalent excessive attention to method, which so often leaves matter as a consideration of very secondary importance. Professor Suzzallo, af Teachers College, Columbia University has written a critical review of recent tendencies in the teaching of arithmetic in the current number of the Teachers College record.

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*Stewart, Alban, A Botanical Survey of the Galapagos Islands. Proc. Cal. Acad. Sci IV Ser., Vol. 1, pp 7–288, 1 map, 18 pls., 1911

Method, as a special professional technique, is all well enough in such a subject as arithmetic, as Professor Suzzallo insists. It is the method which exaggerates the importance of one idea and the tendency to make methods uniform among all schools to which he particularly objects, saying, "It stifles teaching as a fine art, and makes of it a mechanical business. Under these conditions only those actitivies which fit the machine routine can go on. Thus it happens that we memorize, cram, drill and review, and soon the subtler processes of thinking and evaluating, which are the best fruit of education, cease to exist."

Fortunate are the biological sciences, which lend themselves so poorly to methodology; both the inherent nature of these sciences and the temperamental structure of those who cultivate them make it difficult to place the harness of pedagogy on a steed which moves so swiftly.

It is proposed to inscribe on the new laboratory of the Brooklyn Botanical Garden the names of men, ancient and modern, who have made noteworthy contributions to the science of botany. The attempt to obtain a concensus of opinion from living botanists as to who should be awarded the highest places suggests some interesting reflections. Suppose any of these worthies, from Aristotle to Linnaeus, came to Brooklyn and saw their names adorning this temple of fame, and were then shown about by an assistant who should explain the use of various stains and modants, the clinostat, the experiments in chemotropism, the pedrigeed cultures, in short the outfit and work of a modern botanical laboratory. One can easily picture their confusion of mind. And yet it is very certain that few out of the long list of names tentatively proposed could be omitted without evident loss. So slowly did botany become a science; so gradually did its modern content take form; so far removed from its simple beginnings are its modern methods and aims, that we now seem quite out of their world; and yet the early fathers may well be honored for their fruitful thoughts that in various form and measure have helped, even remotely, to build the foundation of the science as we know it.

Volume 14 Number 6

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

JUNE, 1911

CLIMATIC SELECTION IN A HYBRID PROGENY.

D. T. MACDOUGAL.

A number of acorns of *Quercus heterophylla* were secured from some trees on Staten Island, N. Y., in October, 1895, and germinated in the New York Botanical Gardens a few weeks later. The cultures were made for testing the character of the living material grouped under this name by systematists, and with especial reference to the probable parents in case evidences of hybrid origin were found. *

The 55 plantlets obtained were seen to vary widely from each other as to leaf form, although the range of variation on any one plant was small. By the close of 1906 it was seen that the entire lot might be arranged in a linear series, in which the plants at one end bore broad lobed leaves much like those of the red oak, while the individuals at the other extreme resembled the willow-leaved oak (*Quercus Phellos*). This fact was taken as evidence strongly supporting the conclusions of Dr. A. A Hollick and other botantists that *Q. heterophylla* was a hybrid between the red oak (*Q. rubra*) and the willow leaved oak (*Q. Phellos*).

Plants representing the supposed hybrid species have been known for a long time, so that nothing might be said as to the relationship of the plantlets grown and the original cross. The parental trees from which the acorns were taken might have been first generation crosses, or on the other hand they may have represented the *n*th generation with many possibilities as to secondary hybridizations with either parent species or with various recombinations.

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*MacDougal, Hybridization of Wild Plants. Bot. Gaz., 43: 11. 1907.

The chief fact of interest in the present connection was that of the possible reaction af the various types to climate. To test this a series of twelve young trees representing the total range of leaf-variation was taken to the Desert Laboratory at Tucson, Arizona, and exposed to the extremes of the arid subtropical climate at that place. In addition to the direct action of the meteoric factors, the soil was of course widely different from that of the habitat of the plant on Staten Island, since soils are so largely a function of climate.

First of all it was noted that these introduced oaks were attacked by the desert rodents which found their leaves much more to their taste than those of the oaks native on the adjacent mountain slopes. This fact, however, would not have operated very strongly as a selective factor. The hot, dry fore-summers and arid after-summers were the real selective agencies determining survivals, and the notes on the cultures illustrate the fate of such a progeny very clearly.

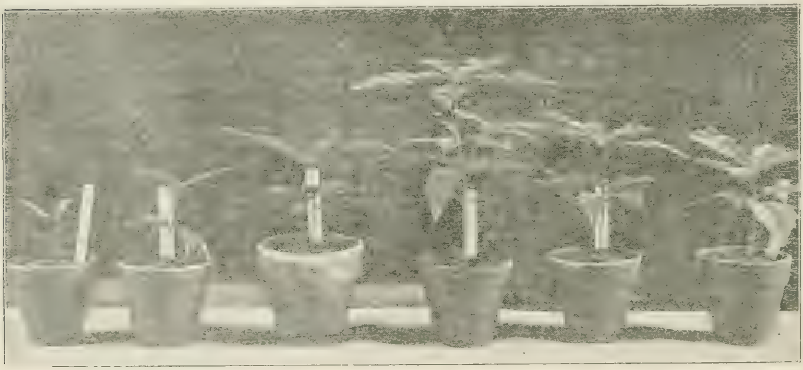

Fig. [illegible]. — Plantlets from progeny of tree of *Quercus heterophylla*. *I* bears leaves not distinguishable from those of *Q. Phellos*, and *VI* resembles *Q. rubra*. *II*, *III*, *IV*, and *V* form a series between *I* and *VI*. Photographed April, 1906.

The entire lot of plants survived the seasons of 1907 and had cast their leaves with the frosts of December, being noted as entirely dormant on Dec. 10. In 1908 the individuals near the middle of the series representing the trees usually passing under the name of *Q. heterophylla* were latest in awakening.

Elimination began in 1909 and by June 13, only five plants of the narrower leaved types survived. On Oct. 22, but four remained. Three of these soon perished, so that the spring of 1910 found but one survivor, that of a type represented by fig. 1, No. III. See also fig. 8, THE PLANT WORLD, Feb. 1907. This remaining individual did not live through the dry fore-summer. The analysis of the observations shows that the leaves supposedly embodying qualities of the red oak were least fitted to endure the desiccating action of the desert, which was endured longer by the narrower more indurated leaves resembling those of the willow-leaved oak. A physiological consideration of the leaves of these types would have led to the expectation of such a result. The suggestion lies near that the action of the climate observed with these plants is one representative of countless occurrences in nature. A linear series from the progeny described above was also established in the New York Botanical Garden, but no report has yet been made as to their action or survival.

OBSERVATIONS ON THE BLOOMING OF TIMOTHY.

CHARLES F. CLARK.

The flowers of timothy, like those of the majority of other grasses, are so small and inconspicuous that they rarely receive the attention given to more conspicucous floral organs. The observations described in the following pages were made by the writer in connection with the timothy breeding experiments which are in progress at the Cornell University Experiment Station and are being published with the hope that they may be of some scientific interest.

The flowers of timothy are borne on a so-called head or spike which is in reality a contracted panicle in which the rachillae are much reduced, giving the inflorescence a spike-like appearance. Each flower, which with its two inclosing outer glumes comprises a spikelet, consists of a flowering glume, a palea, an ovary, two distinct styles with plumose stigmas, and three stamens.

The process of blooming is simply a pushing out of the stamens and stigmas, there being no distinct opening of the flower, or wide spreading apart of the glumes, as in the case of certain other species of grasses. Before blooming the anthers lie close together parallel with the long axis of the flower and closely embracing the folded stigmas. As the anthers are pushed out

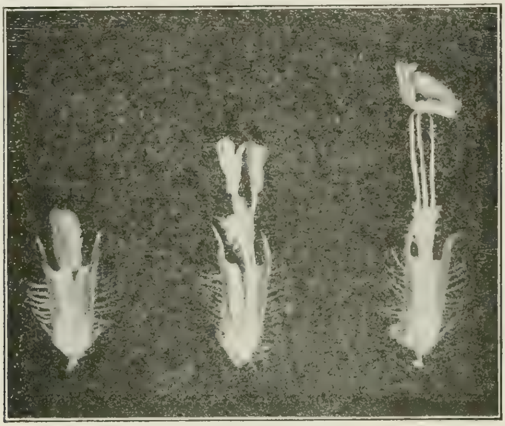

Fig 1.- Different stages in the blooming of individual flowers of timothy.

by the filaments during the process of blooming they carry along the stigmas until they have completely emerged from the outer glumes, when they separate sufficiently to free themselves from the stigmas which spread out and make no further development. The filaments continue to enlogate until they have reached their maximum length. (Fig. 1).

From the time the anthers begin to emerge from the glumes until they are fully extended occupies from three-quarters of an hour to one hour. Dehiscence usually takes place in about one-half hour after blooming is completed so that the whole process of blooming and dehiscence of the anthers is accomplished within an hour and a half. The numbers of day required for the blooming of a single head, *i. e.*, the time between the opening of the first and the last flowers on the same head, varies somewhat according to the individuality of the plant and the climatic conditions which prevail during that period. In the following table are given the results of observations on twenty-five heads, five from each of five plants:

TABLE I.

SHOWING THE NUMBER OF DAYS INDIVIDUAL HEADS WERE IN BLOOM, 1910

PLANT NO.	HEAD NO.	BEGINNING OF BLOOM	END OF BLOOM	NO. OF DAYS IN BLOOM	AVERAGE NO. OF DAYS
	1	July 7	July 15	9	
	2	July 6	July 14	9	
1738.01	3	July 7	July 15	9	9.
	4	July 6	July 14	9	
	5	July 7	July 15	9	
	1	July 9	July 18	10	
	2	July 9	July 18	10	
1744.01	3	July 9	July 18	10	10.
	4	July 9	July 18	10	
	5	July 9	July 18	10	
	1	July 6	July 14	9	
	2	July 6	July 13	8	
1745.01	3	July 6	July 14	9	8.4
	4	July 6	July 14	9	
	5	July 7	July 13	7	
	1	July 9	July 15	7	
	2	July 9	July 15	7	
1746.01	3	July 7	July 15	9	7.4
	4	July 9	July 15	7	
	5	July 9	July 15	7	
	1	July 9	July 15	7	
	2	July 9	July 14	6	
1777.01	3	July 9	July 15	7	7.
	4	July 7	July 15	9	
	5	July 9	July 14	6	

The entire period covered by these dates was favorable for the blooming of timothy with the exception of July 8 and 17 on which days no bloom appeared. An inspection of the fifth column of the above table shows that, in the material under observation, the duration of bloom of a single head varied from seven to ten days. That the period of bloom depends, to some extent at least, upon the individuality of the plant may be seen by comparing the average number of days for those plants in which the majority of heads began blooming on the same date (plants 1744.01, 1746.01 and 1777.01). The end of bloom of plant 1744.01 may have been delayed one day by the unfavorable climatic conditions of July 17 though it cannot be said with certainity that all the flowers which remained unopened on the 17th would have opened on that day if conditions had been favorable. Unrecorded observations of previous years show that several days of unfavorable weather materially lengthen the blooming period.

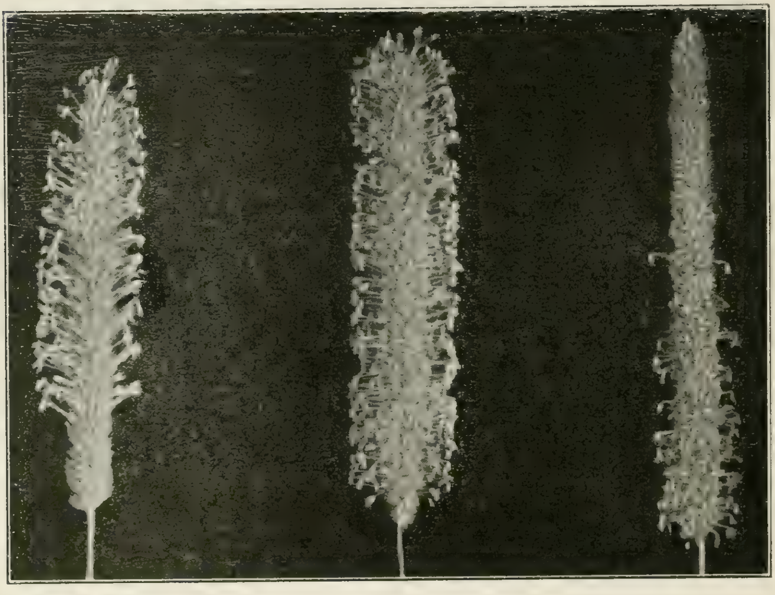

Fig. 2. Different stages in the blooming of timothy heads. (a) Beginning of bloom. (b) Full bloom. (c) End of bloom.

The time of day at which bloomings occur is just before daybreak. As a rule the greater part of the flowers which are to bloom on a given day will be open by three o'clock in the morning, especially if the night has been warm. A few straggling flowers, particularly those on heads or parts of heads which are blooming for the first time may be delayed for an hour or possibly two hours but the great mass come into bloom at approximately the same time. Contrary to general opinion the entire head does not come into bloom at the same time. If the plant is just beginning to bloom, or if weather conditions are not favorabable, the upper third or possibly half of the head blooms first. On succeeding days the blooming will extend downwards until the base is reached. (Fig. 2). If conditions are exceptionally favorable, especially if the plant is well advanced in blooming, the greater part of the head may come into bloom on the same day. There is, however, a narrow zone at the base of the head which the writer has never observed to come into bloom until the end of the blooming period for that particular head. Not all of the flowers in a given area begin blooming at the same time;so that the same part of the head may come into bloom on several successive days.

The blooming of timothy is very closely associated with weather conditions. When these are favorable a large proportion of the flowers on a given head will often come into bloom on the same day while, on the other hand, conditions may be so unfavorable as to entirely prevent blooming. These influences seem to be the resultant of several factors so closely interwoven that they are difficult of exact analysis. An attempt was made in 1910 to determine these factors by means of a self recording hygrometer and thermometer which gives continuous records for humidity and temperature. The results were somewhat inconsistant and failed to give a complete solution of the question. This was probably due in part to the difficulty of securing an accurate humidity record at all times though the presence of other factors may also have been responsible for part of the inconsistencies.

The records, however, showed unanimously that temperatures below 50° F. or above 65° F. and relative humidity below 75° or above 93° at 2 o'clock A. M., were followed by little or no blooming, also that several hours of stationary temperture and humidity during the preceding afternoon and evening, which condition often prevails during a stormy or cloudy period resulted in the entire absence of bloom.

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THE INFLUENCE OF LOW TEMERATURES ON THE DISTRIBUTION OF THE GIANT CACTUS.

FORREST SHREVE.

The work of Müller-Thurgau and of Molisch has shown the variety of ways in which low temperatures may be fatal to different species of plants. Tropical forms may be killed by continual exposure to temperatures just above freezing; other forms survive temperatures slightly below freezing, but succumb on the formation of ice in their tissues. Certain plants will withstand the formation of ice in their intercellular spaces at a few degrees below freezing, but will die at a sudden pronounced lowering of temperature while they are in a frozen state; at the same time that very many arctic species will withstand total freezing together with very low temperatures. In many cases that have been investigated a sudden thawing proves fatal after a given set of cold conditions, although a gradual raising of temperature enables them to survive.

The low temperatures of winter have been recognized for a long time, both in scientific and practical work, as important factors in limiting the northward and vertical distribution of tropical and sub-tropical plants. The fact that these plants vary greatly among themselves in resistance to cold, and the fact that it is different phases of winter cold that are fatal to them, is proved by the lack of a coincidence in the northern limit of distribution among any considerable number of them. The line which marks the extreme southern limit of frost is the most important climatic boundary in restricting the northward extension of perennial tropical species, and it is the line along which the influence of winter cold is the simplest in its operation. In the limitation of the sub-tropical species which extend northward of this line a variety of phases of winter cold without doubt are operative. Chief among these are: the greatest number of consecutive hours during which the temperature falls below freezing; the total number of hours of frost in a single winter; the absolute minimum reached and the length of the winter, reckoned from the first frost of autumn to the last one of spring. For all sub-tropical plants the greatest number of consecutive hours of frost and the absolute minimum are the most important of these factors, while the others mentioned are more strongly operative further north. In any consideration of the geographical importance of the operation of these factors it is obviously necessary to consider only the conditions of the coldest winters, which serve as a check on the movements made by species during the milder winters.

A consideration of the factors which have to do with the distribution and activities of the Giant Cactus (*Carnegiea gigantea, Cereus giganteus*) led me to believe that the greatest number of consecutive hours of freezing is the most important climatic datum in determining its northward range, and led me to investigate its ability to withstand freezing temperatures, and the character of the winter cold conditions within its range. The Giant Cactus belongs to a group of about 65 species of tropical and sub-tropical arborescent columnar cacti all allied to the genus *Cereus*. Of this number *Carnegia gigantea, Lophocereus schottii* and *Lemaireocereus thurberi* are the only ones

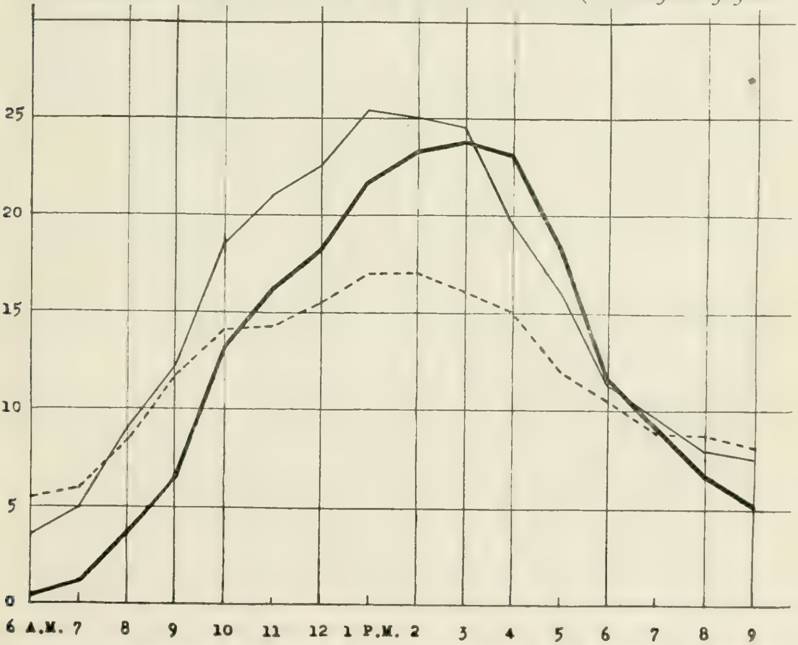

FIG. 1. Curves showing daily march of internal temperature in Giant Cacti on a cold day. Dotted line: air temperature. Heavy line: temperature of cactus 30 cm. high. Thin line: temperature of cactus 8 cm. high.

which extend northward above the limit of frost. The distribution of *Carnegiea* stretches from the mouth of the Yaqui river, in Sonora, northward along the Gulf of Lower California and the Colorado river to the mouth of the Bill Williams river in Arizona, and eastward to the Santa Rita mountains in southern Arizona, and up the various tributaries of the Gila river to approximately 3900 feet (1190 m.) elevation. The vertical limit of occurence of Giant Cactus in the desert mountain ranges in the center of its area is 4500 feet (1375 m.), while its abundant occurrence ends rather abruptly at 4200 feet (1280 m.). The distribution of the giant Cactus to the westward of the Colorado river is undoubtedly limited by the low summer rainfall of interior southern California.

In order to ascertain the character of the winter cold conditions within and just outside the range of the Giant Cactus an examination of climatological records was made for the four localities in Arizona at which thermograph records are regularly secured. Yuma, Phoenix and Tucson are within the range of *Carnegiea*, Flagstaff being considerably above it. The figures in the following table are for the winter of 1909-1910—the most severe for several decades.

STATION	YUMA	PHOENIX	TUCSON	FLAGSTAFF
Elevation (feet)	141	1108	2663	6907
Elevation (meters)	43	337	812	2106
Number of days with freezing temperature	13	14	15	193
Number of hours of freezing temperature	32	89	126	2200
Greatest number of consecutive hours of freezing temperature	8	13	19	132
Minimum temperature during greatest number of hours (Fahr.)	25	23	17	−22
Same (Centigr.)	−4	−5	−8	−30

The most important figures of this table are those which show that the Giant Cactus is capable of withstanding 19 hours of continued freezing temperature and as low a minimum as 17° F.(−8.3° C.). It may be noted that Flagstaff possesses a climate much more rigorous than that of the other stations. The fact that Tucson is only 1300 feet below the limit of the Giant Cactus, while Flagstaff is 3000 feet above it indicates that the cold conditions at Tucson are nearer those which limit the Giant Cactus than are those of Flagstaff.

Curves drawn to show the changes of intensity of climatic factors,as followed from one locality to another distant one, commonly show a smooth rise or fall. However, on passing from lower to higher latitudes or altitudes the number of consecutive hours of freezing becomes gradually greater until the point is reached at which days without a mid-day thaw are first encountered; there is then a sudden rise from about 22 hours of frost to from 36 to 42 hours, according as the fall and subsequent rise of temperature are abrupt or gradual. In other words this factor is unique in that the curve expressing its changes of intensity possesses a sudden vertical rise, or indeed a number of such rises. The line along which this takes place in the severest of winters is bound to be an important limit of plant distribution, at least it is so along the line of sudden rise which lies nearest the absolute frost line. It has not been possible to locate this isohoral line exactly from the climatological

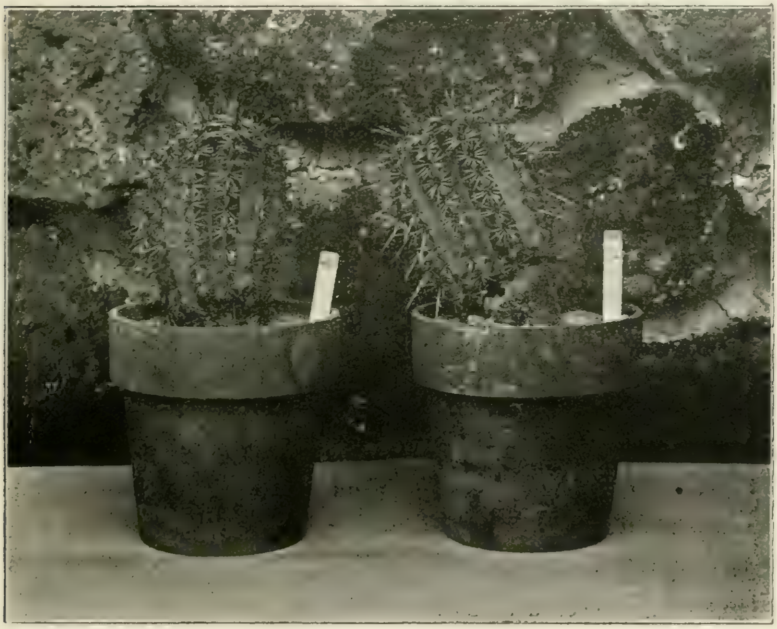

FIG. 2. Young Giant Cacti frozen 42 and 29 hrs., respectively, showing destruction of tissues at base.

data obtainable for Arizona, but the few figures at hand, when plotted in relation to altitude, and supplemented by the temperature data accumulating from the work of MacDougal and of the writer on the Santa Catalina mountains, show a strong probability that the line lies in the vinicity of the limit of the *Carnegiea*, which is also the limit of *Parkinsonia microphylla, Cercidium torreyanum, Fouquieria splendens, Encelia farinosa Acacia greggii, Franseria deltoidea, Cassia covesii* and a number of other characteristic desert species.

The stout form and high water content of the Giant Cactus suggested the necessity of investigating the relation between the daily curve of its internal temperature and the daily curve for the air, both for the sake of learning whether a given number of hours of freezing air temperature meant as long a subjecting to freezing for the cactus and whether as low a minimum would be reached by the cactus. With this object incubator thermometers were inserted to a depth of 3 cm. in two individuals, 8 cm. and 30 cm. high respectively, and the temperature of the air was read simultaneously. Readings were also made on the north side of an adult cactus at depths of 3 and 7 cm. All the observations made showed a rapid response on the part of the cactus to the changes of air temperature, and all showed a greater amplitude in the daily curve for the cactus than in that for the air, excepting in the case of the deeper thermometer in the adult cactus. The curves shown in fig. 1 exhibit the data secured from the young cacti during a clear day (Feb. 22, 1911) and one of the coldest nights of the winter of 1910-1911. Observations on the same cacti on a completely cloudy day showed a rise of temperature for the larger one almost exactly parallel with the march of the air temperature Clear days are usually juxtemporaneous with the coldest nights of winter, and under such conditions insolation carries the diurnal temperatures of the cactus above that of the air, while radiation, together with a slight amount of transpiration cooling, carries the nocturnal temperature below that of the air. In other words the surface cells of the cactus are exposed to lower temperature than those indicated by the air thermometer, and the cactus is subjected to a slightly greater number of hours of freezing temperature than is indicated by the air thermograph trace. The actual conditions of temperature for a given individual are a function of the amount of heating or precooling it has received during the preceding day.

In order to observe the actual effects of exposures to freezing temperature varying within the limits of duration common to central Arizona, a number of young Giant Cacti were potted, of such size that they could be placed in large freezers. The fact that the Giant Cactus is able to survive for months without renewed supplies of water led me to preserve only the main parts of the root system, and to leave the potted plants without watering previous to their use. Three sets of experiments were made, in which a total of 11 plants of 18 to 28 cm., height were used and pot-grown seedlings less than 1 cm. in height. In each of the three sets of experiments there was one of the larger cacti in which an incubator thermometer was inserted to a depth of 3 cm., with its scale projecting above the lid of the freezer, while there was another thermometer placed to show the air

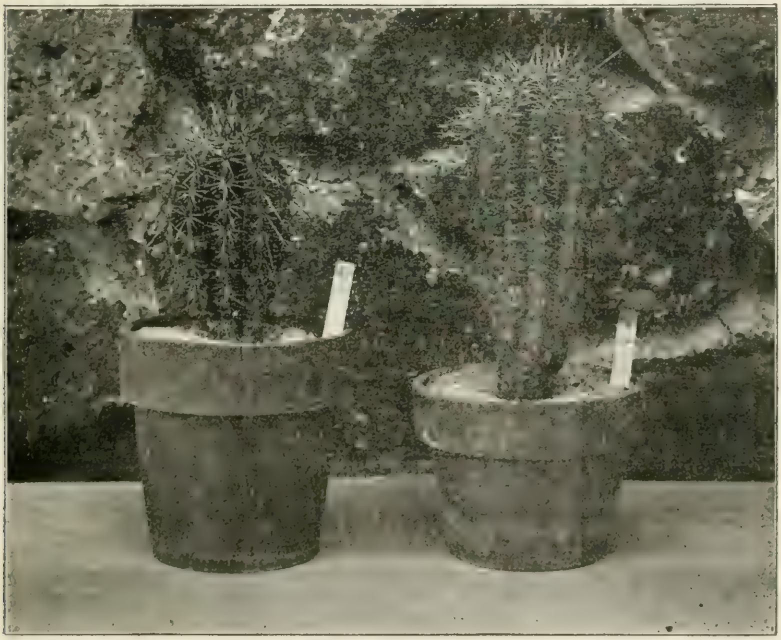

FIG. 3. Young Giant Cacti frozen 6 and 15 hrs., respectively, showing uninjured condition.

temperature surrounding the cactus. In the other experiments of each series only the air temperature was read. The freezing mixture of ice and salt was renewed as required. The several experiments differed in the amount of pre-cooling given, and in the length of time the plants were subjected to an air temperature below freezing. In each case the cacti were allowed to cool gradually by opening the lid of the freezer and allowing the ice to melt during the next 12 hours. This always resulted in surrounding the cacti with air that was cool but not below freezing. After from 12 to 20 hours they were removed from the freezers and placed in a cool room. On the following day they were placed in a green house where the temperature rose to 70° to 80° F. in midday.

Following are given the corrected figures for the temperature of the air (C.) and of the cactus at the outset of the three tests in which thermometers were placed in the tissue of the cactus.

CACTUS No. 1				CACTUS No. 5				CACTUS No. 12			
NOT PRECOOLED				PRECOOLED 15 HRS. AT 3° TO 5° C.				NOT PRECOOLED			
		Air	Cactus			Air	Cactus			Air	Cactus
Jan. 14,	5 P.M.	put in		Jan. 22,	6 A.M.	put in		Jan. 25,	2 P.M.	put in	
	6 P.M.	0.	10.5		7 A.M.	−8	−3		4 P.M.	−6	4.5
	7 P.M.	0.	6.8		8 A.M.	−8	−3		5 P.M.	−6	2.0
	8 P.M.	0.	4.0		9 A.M.	−7	−3		6 P.M.	−5	0.5
	9 P.M.	0.	2.0		10 A.M.	−8	−3		7 P.M.	−4	0.0
	10 P.M.	−1.0	1.0		11 A.M.	−8	−3		8 P.M.	−2	0.0
	11 P.M.	−3.0	−0.5		12 N.	−8	−3		9 P.M.	−7	−0.5
	12 M.	−3.5	−2.0						10 P.M.	−7	−0.5

The temperature of cactus No. 1 fell no lower than −4° and it was kept between that temperature and zero for 42 hours. Cactus No. 5 was precooled, and when placed in the freezer was cooled vigorously and taken as low as −11°. It was not allowed to go above −5°, being kept at temperatures below freezing for 29 hours. Cactus No. 12 was taken only to −3° but was kept below freezing for 46 hours. In each case the plant was allowed to stand in the greenhouse for several weeks after freezing, alongside unfrozen controls of the same size which had been gathered at the same time and treated in every other respect in the same manner. Within two weeks after freezing all three cacti had begun to show a blackening of their tissues around the base, which through a disturbance of their turgidity lost them their natural erect position. By four weeks after the freezing No. 12 had become black and soft throughout its lower half. Six weeks after the freezing No. 1 and No. 5 were photographed (Fig. 2) so as to show the injured tissues at the base. These individuals were kept for another month and failed to heal or show signs of recovery, at the same time that the controls were still in normal condition.

Seven other young cacti were subjected to freezing temperatures for periods as follows:

No. 4	9 hrs.	No. 19 (precooled 4 hrs.)	6 hrs.
No. 9	6 hrs.	No. 24	14 hrs.
No. 13	15 hrs.	No. 25	14 hrs.
No. 18 (precooled 2 hrs.)	6 hrs.		

None of these individuals showed signs of injury from frost on being kept for two months in the greenhouse with the others. Two of them, No. 18 and No. 13, are shown in Fig. 3.

Seven seedlings of Giant Cactus one year old were subjected to periods of freezing of from 6 to 42 hours. None of the three subjected to 42 hours survived, but one subjected to 9 hours, and one to 15 hours perished. The fact that the seedlings were hot-house grown, more succulent and less heavily cuticularised than outdoor seedlings probably are [*] prevents me from drawing any conclusions as to their being less resistant than the juveniles and adults.

Although the conditions under which these experiments were done were somewhat artificial as respects the coldness of the soil and the high humidity of the air surrounding the plants at the time of exposure to cold, yet I cannot believe that these conditions affect the results materially. The seven experiments in which individuals were subjected to periods of from 6 to 15 hours of frost reduplicated conditions under which the Giant Cactus is placed in nature, and their survival was no more than a confirmation of what might be observed in the field at appropriate times. The three experiments in which individuals were given from 29 to 46 hours of freezing reduplicated the conditions to which they would be subjected at higher altitudes and to the northward of their natural range, and they indicate the inability of *Carnegiea* to withstand such longer durations of cold. I made no examination of the tissues of the cacti which were given the longer durations of frost. It is probable that 20 to 36 hours of frost would kill some individuals and would fail to kill others, and it is only the jump in the controlling climatic factor, to which allusion has been made, that makes the natural operation of this factor decisive and limits the distribution of *Carnegiea* in an abrupt manner. The occurrence of a single day without mid-day thawing, coupled with a cloudiness that would prevent the internal temperature of the cactus from going above that of the air, would spell the destruction of *Carnegiea*; and the parallel evidence of the climatological records and of the experiments which have been described appears to explain the limitation of its northward distribution.

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[*] I have never seen any spontaneous seedlings of this size in the field, nor has anyone else, so far as I know.

The branched arborescent cactus *Opuntia versicolor* ascends in the desert mountain ranges to 5,800 feet (1,768 m.) and the small form *Echinocereus polyacanthus* reaches 7,800 feet (2,380 m.), the highest altitude attained by any species of cactus in southern Arizona. *Opuntia versicolor* is common on the desert mesas and reaches its highest limit only on ridges and southern slopes, while the highest individuals of *Echinocereus polyacanthus* are found on cliffs and rocks where they are likely to be exposed to insolation and mid-day thawing. Freezing experiments similar to those described were carried out on young individuals of *Opuntia versicolor* 5 to 25 cm. high and on adults of *Echinocereus polyacanthus*. The 11 individuals of these species used were given various lengths of exposure up to 66 continuous hours of freezing without any injuries or fatalities. The longest of these exposures is about the length of time that frost would supervene when two consecutive days were without thaw, a condition which must exist in the mountains of Arizona at 7,800 feet altitude in every severe winter. The smaller and more widely distributed types of cacti must all be more resistant to frost than are any of the arborescent columnar or the branched arborescent types. In the Rocky Mountains

Echinocactus simpsoni is reported to range up to 11,000 feet altitude, while *Opuntia missouriensis* has been collected by Prof. J. Macoun on the Peace River in Athabasca at lat. 56 deg. 12 min. An indication of the length of greatest exposure to frost for Athabasca can be surmised from the fact that the weather records for Havre, Montana, 250 miles south of the limit of *Opuntia missouriensis,* show a continuous period of 333 hours (13 days) of frost in the winter of 1909-1910.

In summarising it is necessary to bear in mind that the physical conditions of desert regions are such as to give the daily temperature curve a much greater amplitude than it has in moist regions. At Tucson there are very many days on which the minimum and maximum temperatures are 50° F. (30° C.) apart, and on exceptional days still further than this. The power of insolation to raise the mid-day temperature is so great in all deserts that occupy low latitudes and altitudes, that however cold the nights may be the daily maximum is carried above the frost line. There have, in all probability, been no days at Tucson in many hundreds of years on which the air temperature remained below freezing all day, and the ability of insolation to raise the internal temperature of the Giant Cactus makes it still more certain that none of the individuals of this species now living have endured more than 20 hours of frost, and periods as long as these are due solely to partially cloudy days of the winter rainy season.

The winter temperature conditions of the higher altitudes in the desert mountain ranges are very well indicated by the figures given for Flagstaff, which itself occupies a pass in a range of mountains surrounded by desert. Any attempt to explain the limitation of the bulk of the desert species to altitudes of 4000 to 5000 feet in the desert mountains must take account of the winter cold factors. Between those altitudes the conditions of atmospheric and soil aridity are somewhat less severe than on the desert floor and foot-hills, and between 5000 and 7000 feet these conditions,as indicated by the natural vegetation, are materially less severe. Between 5000 and 7000 feet, however, the vegetation is extremely open, giving abundant opportunity for the invasion of desert species into a region in which the atmospheric and soil moisture conditions are more favorable, without by any means being moist. My observation of numerous species of desert plants which have been artificially irrigated or protected from extreme insolation shows that there is no one of them to which a slight amelioration of the atmospheric aridity, or a slight increase of the soil moisture, or of the number of times the soil is made wet, does not permit both a greater vegetative and a greater reproductive activity. These slightly improved conditions are to be found between 5000 and 7000 feet altitude in the desert mountains, but they are to be found only where the winter cold conditions are such that desert species are unable to survive. In other words the failure of desert species to establish themselves in a region which seems at first sight to be a more favorable one than that in which they are common, is due to the operation of a factor entirely distinct from those which have to do with the apparent favorableness.

The Desert Laboratory,
Tucson.

BOOKS AND CURRENT LITERATURE.

ALTITUDINAL LIMITS IN MEDITERRANEAN VEGETATION—Koch's "Contributions to Our Knowledge of Altitudinal Limits of Vegetation in the Mediterranean Region" * emphasises especially and seeks to define the temperature relations of the vegetation, although recognizing the concurrent action of other factors. In Southern France, the Apennine peninsula, the Balkan region, Greece, Asia Minor, Syria and northern Africa there is observed a horizontal distribution of the Mediterranean vegetation, of the forests, and the alpine vegetation and a vertical extension of the Mediteranneän vegtation as a whole and of such representatives as *Laurus nobilis*, *Myrtus communis*, *Fagus sylvatica*, *Quercus ilex* and others. The principal results of the author's studies may be summarized as follows: In the Mediterranean region a parallelism of the lower and upper limits of plants is observed, with departures due to local influences. The upper limits are influenced by the temperatures of June and July. In general the temperature of January influences the outline of the upper limit of characteristic Mediterranean plants, while the July temperature influences that of the middle European plants ocurring in the regions studied. The isotherm of five degrees C. for January fixes the upper limits of the Mediterranean vegetation, and the isotherm of ten degrees for July that of the forest; the upward curve of these isotherms defining in general the upward extension of the altitude limits in question. The annual precipitation has a positive influence on the altitudinal limits of the middle European forest trees, while its influence on the xerophilous representatives of the Mediterranean vegetation is for most part negative. The altitudinal limits of nearly all the plants studied rise on approaching the African desert region, the continental parts of Asia and the Pyrenean peninsula; while in general the least upward extension is observed in the Apennines and in the Balkan peninsula.—V. M. SPALDING

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* Koch, M., Beiträge zur Kentnis der Hohen grenzen der Vegetation im Mittelmeergebeite Dissertation, Halle, 100 pp. 1909.

THE PEAT DEPOSITS OF FLORIDA. Harper has published a report* of his reconnaisance of the peat deposits and peat forming areas of Florida. In addition to a considerable mass of information relative to peat, the report contains the best description of the vegetation of Florida which has yet been made. Fourteen "natural divisions" of the state are outlined by map and briefly characterised as respects their topography, soils and vegetation. The low elevation and immature topography of Florida give rise to a bewildering variety of palustrine areas, which have naturally received more attention in this paper than the upland vegetation. Harper has described some 27 types of marshes, swamps, bogs, "prairies," "bays" and other formations with wet substratum. He has used the character of the vegetation in distinguishing these areas and has followed the refreshing custom of giving them either such names as are locally used for them or else simple designations that are descriptive of their vegetation or their most obvious physical characters. The alluvial and estuarine swamps and marshes appear to be clearly differentiated from those in which the water is calcareous, the latter group embracing the great majority of the areas described. Also of importance in differentiating the palustrine areas are such matters as whether water is running or stagnant, constant or seasonally intermittent in level, and whether the area is young or old, in terms of the degree to which peat formation has gone on. It appears more than probable to the reviewer that many of the palustrine areas do not possess constellations of physical conditions which are sufficiently distinct to explain the differences in their vegetation, as *e. g.* the Gum (*Liquidambar*) swamps and the Tyty (*Cliftonia*) swamps of western Florida. In fact, the work of Harper suggests a most promising field for work on the relative operation of physical and historical factors in a comparatively recent set of habitats.—F. S.

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*Harper, Roland M., Preliminary Report on the Peat Deposits of Florida. Third Ann. Rep. Fla. State Geol. Surv., pp. 197, pls. 17-28, figs. 17-30, 1 map. 1910.

GREEK CLIMATE AND VEGETATION.—Kontos, in a paper* on the influence of climate on Greek forest vegetation, has discussed the climate of coast and hill country, its changes corresponding to latitude and altitude, distance from the sea, direction of winds in relation to rain, geographic features and climatic conditions incident to aspect and exposure. The influence of these various climatic factors in their relation to the forest vegetation of Greece is considered in some detail, as, for example, in regard to the influence of wind in determining the distribution of xerophytic, hygrophytic and tropophytic species of trees, and a somewhat extended account is given of the various forest zones a correlated with climatic factors.—V. M. SPALDING.

NOTES AND COMMENT.

British botanists have shown no little activity within the past year in phytogeographical work. Moss, Rankin, and Tansley have reported in *The New Phytologist* on "The Woodlands of England," attempting to deal, in a general way, with the character and distribution of different types of natural and seminatural woodland in England. Types of English woodlands are defined in connection with details as to composition and ecological factors. It appears that "climate shows its effects in ascending the larger hill masses, but in the lowlands it does not materially affect the distribution of dominant trees, although it influences certain species of the ground vegetation. Soil is the greatest differentiating factor and influences the distribution of woodlands through differences in mineral content, and humus-content".

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*Kontos, P., Epidrasis epi ten helleniken dasiken blastesin toy hellikoy klimatos. 78 pp Athens, 1909

The same botanists have recently published other papers. Rankin describes, in *The Naturalist*, the "Peat Moors of Lonsdale," with special reference to the lowland Moors, which are either littoral or lacustrine. The former, located in the drainage area around Morecambe Bay in north and west England, are a distinct physiographic feature, and their vegetation shows relationship with the fens of eastern England. "The first vegetation grew in silt under water, and in time became swamp moor, to be followed later by heath moors; these phases being traceable from existing vegetation and also from examination of remains in the peat, the lowest strata consisting of sedges and rushes, not birch, as in the case of most upland peat moors."

Moss, in *The New Phytologist*, discusses "The Fudamental Units of Vegetation," tracing the historical development of the concepts of the plant association and the plant formation from Humboldt and Griesebach down to the works of living writers. Warming's definition, "an association is a community of definite floristic composition within a formation" may be compared with that of Moss, "A plant formation comprises the progressive associations which culminate in one or more stable or chief associations, and the retrogressive associations which result from the decay of the chief associations, so long as these changes occur on the same habitat."

Aside from the writers cited, all of whom have at least formulated a problem of scientific interest and importance, toward the solution of which their work has contributed, there are others who have for the most part limited themselves to recording certain facts of distribution, which, like the lists of species given in systematic periodicals, are likely enough at some future time to have more value than is apparent at present. On the whole, however, it is plain that if to the recent work of European botanists there is added that of American investigation in the field of phytogeography, there is reason to feel that notwithstanding inherent difficulties this department of botanical study is more and more approaching the exactness characteristic of an advanced period of development.

An article by Mr. S. B. Parrish in recent numbers of *Muhlenbergia* on "The Southern California Juncaceae" is worthy of attention. This is concluded in the December, 1910, number by a tabular statement of regional and geographical distribution, with a summary from which one at a glance may note which of the twenty-two species listed are restricted to North America, which ones reach South America, Europe, and Japan, which are confined to the Pacific coast of North America, and those that are endemic in Southern California. The descriptions indicate character of habitat as well as distribution in altitude, and include critical notes on the constancy of characters. With this paper in hand one is in a position to study with satisfaction the difficult group of which it treats,over the territory covered by the author,and to thank him for smoothing the way by telling the exact facts in clear English with the succinctness and mature judgment that come from many years of close observation and habits of conscientious expression. In another number of the same journal there is a paper in which the writer makes new species out of such characters as the following: "The perianths are larger in the species here proposed as new; but a better mark * * * is the great length of the oblong and leaf-like segments of the involucre." Comment is unnecessary.

In a recent bulletin of the Bureau of Plant Industry (No. 204) entitled "Agricultural Explorations in the Fruit and Nut Orchards of China," Mr. Frank M. Meyer gives a readable account, illustrated by recent photographs, of numerous wild and cultivated plants studied by him in China and Manchuria, with interesting suggestions as to habits and the availability of hardy varieties for extending the range over which a given fruit may be cultivated in the United States. The need of discrimination in the importation of fruits is suggested by a judgment of one fruit as quoted: "it depends on what you eat them as; as turnips they are certainly fine, but as pears I would rather not express any opinion."

A story of fascinating interest is the history of the coconut palm in America as it has been worked out, partly from historical and ethnological evidence and partly on botanical grounds, and set forth in Contributions from the National Herbarium by O. F. Cook. The first contribution of the author to this subject appeared in 1901, and the results of his further studies are summarized in the present paper (Vol. 14, part 2). It is shown that all the palms related to the coconut,comprising about 200 genera and 200 species, are natives of America, with the possible exception of a single species, the West African oil palm. The structure af the fruit, contrary to a long standing assumption, does not indicate adaptations for maritime distribution, but rather for protecting the embryo, assisting in germination, and establishing the young plants in dry interior localities. The habits of the coconut palm afford no indication that its original habitat was on the seacoast, and in fact it does not appear to be able to sustain itself under littoral conditions without the assistance of man. It has not been able to establish itself as a wild plant on any tropical coast, but is always crowded out by other vegetation after human care is withdrawn. The relative uniformity of the coconuts of America is in accord with the probability of an origin in this hemisphere. The discovery of distinct varities in isolated localities accords with the probalities that the many diverse varities in the Malay region, for example, have arisen like other cultivated varities, through segregation and mutation rather than by gradual evolution and natural selection. It seems therefore "that the botanical romance of the coconut, protected by its thick husk and floated from island to island in advance of human habitation, must go the way of many other pleasing traditions," and that the opinion of De Candolle, based on such evidence as he could obtain, that the coconut palm was introduced into South America and the West Indies by European settlers has no warrant in history.

Teachers will find much useful information in Farmers' Bulletin 428 on Testing Farm Seeds in the Home and in the Rural School, while Bulletin 431 of the same series, on the Pea nut, well illustrated and well written, is also filled with a variety of valuable data which could hardly be found elsewhere in such convenient and accessible form. These and still other bulletins of the Agricultural Department are accessible practically to every citizen of the United States who cares to make use of them. The great service thus rendered to education by the Department, quite apart from its immediate function of supplying farmers and horticulturists with practical information, is not likely to be overestimated.

We are in receipt of the first number of the *Pomona College Journal of Economic Botany*, a quarterly which has for its aim the advancement of sub-tropical horticulture and agriculture. The editor, Mr. C. F. Baker, is a man of long experience in the tropics,and the spirit of his "Foreword" in the opening pages of the journal, together with the character of its contents, would indicate that it will merit a hearty support. The address of the editor is Claremont, Cal., the subscription is $1.00.

Volume 14 Number 7

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

JULY, 1911

THE RELATION OF THE OSMOTIC PRESSURE OF THE CELL SAP IN PLANTS TO ARID HABITATS.

BURTON EDWARD LIVINGSTON.

Plant physiology and the various fields of its application are indebted to Hans Fitting[*] for the first extensive study of internal osmotic pressure as a plant character ecologically related to environmental conditions. Although numerous determinations of the magnitude of the osmotic pressure in plant cells, both by the method of plasmolysis and by that of the freezing point, have already been carried out, these have dealt with comparatively few plants and with restricted ranges of conditions. From the hitherto available information, the usual pressure in the cells of the ordinary land and fresh-water plants may be taken as from 5 to 11 atmospheres (Pfeffer-Ewart 1: 139), but cases are on record of pressures much outside of these limits. So far as I am aware, the highest pressure hitherto observed in ordinary plants is that of 40 atmospheres, found by Pfeffer in the internodes of grasses (citation in Jost Gibson, p. 419).

In a very thorough-going study of the osomtic pressures ocurring in the foliage of a large number of plant forms growing naturally in the vicinty of Biskra, Algiers, Fitting finds that the pressure of the cell sap may often reach magnitudes very much higher than those mentioned above. In this study, the leaf epidermis, or sections of mesophyll—always from leaves gathered in the forenoon of the same day—were tested plasmolytically with potassium nitrate solution in the usual manner. The solubility of potassium nitrate limits the possible osmotic pressure of an aqueous solution of this salt to about 100 atmospheres [*] and it was found impossible in many cases to obtain plasmolysis with the saturated solution. In certain of these cases a saturated solution of sodium choloride, containing 5.42 gram-molecules per liter, produced plasmolysis. [†]

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[*] Fitting, Hans. Die Wasserversorgung und die osmotischen Druckverhälnisse der Wüstenpflanzen. Zeitschr. f. Bot. 3: 209-75, 1911.

As many plants as possible, from a number of different soils, were tested to determine the influence of the latter (especially in regard to their moisture content) upon the magnitude of the foliar osmotic pressure. In many instances it was possible to test the same species on several soils. The main soil types considered were: The mountain desert (Felsen-Wüste) of the Chaine de Sfa, the boulder desert (Geröllwüste), dry soil, formerly cultivated but now abandoned (trockenes, wüstenähnliches Kulturland), sand dunes, saline swamps and moist, non-saline soil (either irrigated of near water in the Oued Biskra. The results obtained are so important, not only with regard to the possible magnitudes of plant osmotic pressure, but also with reference to the relation of this pressure to environmental conditions, and to our general knowledge of the fundamental water relations of plants, that I have selected from Fitting's tables a few of the observed pressures for presentation here. These are given below, the quantities being all in terms of gram-molecules of potassium nitrate per liter,[**] and all referring to the leaf epidermis. In many cases the mesophyll was found to exhibit a somewhat higher pressure than the epidermis. In the mountain desert and in the boulder desert the conditions, both of plant and soil are in close agreement, so that I have not deemed it worth while to quote separate examples for these two soil types. For such details, as well as for determinations upon many more forms, the reader must consult the original paper.

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[*] The most concentrated solution used by Fitting was saturated at 22° C., and contains 2.96 gram-molecules per liter. This concentration is assumed as 3–normal, with a pressure of about 100 atmospheres.

[†] This method of using as a basis for dilution a solution saturated at a given temperature, avoiding ,as it does the use of the balance, has much to reccommend it for field studies which require the preparapration of salt solutions. There is no advantage in haying the stock solutions, from which dilutions are to be made, of any integral number of gram-molecules per liter.

[**] These may be reduced, approximately, to atmospheres by multiplying by 36.9, 34.07, or 33.3, according as the observed isotonic solution approaches respectively, 1.0, 2.0, or 3.0 gram-molecules per liter (see original paper).

PLANTS.	Mount'in or boulder desert	Dry soil, formerly cultiv't'd	Sand dunes	MOIST SOIL	
				Saline	Non-saline
TREES					
Phoenix dactylifera				1.2–1.5	0.8–1.2
LARGE BUSHES,					
Nitraria tridentata	1.2		1.2	0.8–1.2	
Rhus oxycantha	3.0+				1.5–2.0
Zizyphus lotus	1.0–1.2				0.5–0.6
SMALL BUSHES,					
Suaeda vermiculata	3.0+	2.0	3.0+	3.0+	
Suaeda pruinosa	3.0+	3.0–3.0+	3.0+		1.5
Traganum nudatum	3.0+		1.0–1.2		
Zygophyllum cornutum	1.2–2.0+		1.5–3.0	1.2–2.0	
Opuntia					0.4–0.5
PERENNIALS,					
Frankenia thymifolia	3.0+	1.5–3.0		0.8–1.5	0.8
Fagonia glutinosa	0.9–3.0+		0.2–0.3		
ANNUALS,					
Adonis microcarpa	1.0–1.2	0.8–1.2	1.0–1.2		0.5–0.8
Anagallis coerulea	0.3–0.5				0.3–0.4
Cleome arabica	0.8–1.0		0.4–0.6		0.4–0.5
Mesembryanthemum nodiflorum	3.0+			1.0–1.2	1.0–1.2
Wheat					0.6–0.8

If we compare the isotonic concentrations determined by Fitting with those which are usual with ordinary plants in humid regions (0.15–0.3 gram molecules of potassium nitrate per liter), we find that the highest pressure developed by those desert forms is more than *thirteen* times what we have hitherto considered as *usual*. They are perhaps three times as great as the pressure observed in grass stems by Pfeffer. Hereafter the highest pressures observed for ordinary green plants must be cited as at least over 100, perhaps as high as 130 atmospheres, or even higher. By the use of other solutes—perhaps cane sugar is the most promising—it should be possible to determine these high pressures more accurately.

It is to be noted especially that *not all* forms growing under the most arid conditions are capable of exhibiting these enormous pressures; *Anagallis coerulea*, for example, even in the driest situations, fails to develop pressures above that of a half normal potassium nitrate solution. Tests by taste show that many, but not all, of the plants which exhibit great pressure are highly charged with sodium chloride. Some have an acid taste, but it is clear that high osmotic pressure is not necessarilly correlated with the presence of sodium chloride nor with acidity. To determie the nature of the solutes to which the osmotic pressure is due must remain a problem for the laboratory, not for the field.

Turning our attention now to the influence of the substratum upon the magnitude of the foliar pressure, it appears that the highest pressures are usually manifest in plants growing in dry soil, and that extremely high pressures are not met with in moist, non-saline soils. The pressures exhibited by the plants growing in irrigated land are, however, usually somewhat higher than those met with in the humid regions. In this connection Fitting calls attention to Stange's experiments with water cultures, *which showed that with nutrient solutions of high concentration the osmotic pressure of leaves and roots is much higher than otherwise. Thus non-halophytes like wheat, bean, pea, etc., (which in weak solutions or on ordinary moist soil have pressures about isosmotic with a 0.25 normal solution of potassium nitrate) develop pressures about equivalent to that of a 0.6 normal solution when grown in concentrated liquid media or saline soil. Salt-accumulating forms, such as *Plantago maritima*, *Salsola kali*, etc.,(usual pressure, in non-saline soil, about equivalent to that of 0.25 normal sodium chloride solution) exhibit pressures about isosmotic with a 0.76 normal solution of the salt, of even higher, when grown in concentrated media. The irrigated soil of Biskra is much more highly charged with salts than the cultivated soils of the humid regions, and our author believes that this fact accounts for the occurrence of rather high pressures in the fields of the desert oasis. While wheat has a usual pressure balancing about 0.25 normal potassium nitrate solution, and Stange succeeded (through the use of a concentrated substratum) in increasing this to that of a 0.6 normal solution, the pressure of this plant as grown at Biskra is found by Fitting to be equivalent to that of a 0.6 to 0.8 normal solution of the same salt. It is interesting to note, as does Fitting, that the little annual *Anagallis coerulea* exhibits pressures little if at all higher in the most arid conditions than on the irrigated land. It barely succeeds at all in extremely dry soil. Variations in the moisture supply appear not to produce any corresponding alterations in the foliar pressure of this plant.

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*Stange, B., Beziehungen zwischen Substratkonzentration, Turgor und Wachstum bei einigen phanerogamen Pflanzen, Bot. Zeitg. 50: 253. 1892.

The pressures found in plants upon the dry cultivated land are much higher than those upon irrigated soil, and closely approach, or actually attain, the magnitudes obtained with plants from the true desert.

That *Opuntia* is found at Biskra only in irrigated land makes it appear that this form is unable to succeed under the natural conditions of this locality. Like *Angallis*, this cactus was not found with high pressures, but, as noted, *Angallis* is able to grow, to some extent at least, in very dry situations. The Opuntias tested by Fitting were shrivelled and apparently not in good condition, from lack of moisture. Fitting calls attention to the fact that the very low concentration of the cell sap (isotonic with 0.4 to 0.5 normal potassium nitrate) exhibited by his Opuntias is in excellent agreement with the results obtained by myself (Publication 59 of the Carnegie Institution, 1906) at Tucson, for another species of this same genus, as well as for other succulent cacti. MacDougal (Publication 129 of the Carnegie Institution, 1910) has had the osmotic pressures of the expressed juices of *Opuntia* and other cacti determined by the freezing point method, with the result that, though the pressure was found to increase considerably with the dryness of the season, yet the tests yielded no very high magnitudes The xerophytism of this sort of plants is then, not correlated with high osmotic concentration of the cell sap. Fitting emhasises the fact that these succulent cacti are not to be considered as types of extreme xerphytes.

Only three plants were tested for both irrigated (non-saline) soil and that of wet salt spots. One of these (*Mesembryanthemum*) showed the same pressure in both situations, while the others (*Phoenix* and *Frankenia*) showed a considerably lower pressure in the irrigated soil. The couse of the lower pressure in the last two cases is considered as related to the greater resistance to water absorption produced by the high concentration of the salt, swamp water, that is, to *external* osmotic pressure. Thus high osmotic pressure of the soil solution is seen to affect the organism in the same manner as does actual dryness of the soil.

Several salt-accumulating forms, growing in wet salt-spots showed pressures equivalent to that of an 0.8 to 1.5 normal solution of potassium nitrate, while the same forms in the much less saline and at the same time much drier desert soil exhibited pressures isotonic with a 1.5 to 3.0 normal solution. "Thus the pressure is the highest, not where salt may be most easily accumulated, but rather in the driest positions, where salt is much less easily available." (p. 249).

This must not be taken to mean (a point which our author does not mention) that *actual* dryness is more potent in increasing the pressure of the call-sap than is that form of *physiological* dryness which is due to high concentration of the soil solution; it seems to denote simply that the *magnitude* of physiological dryness in the saline swamps does not equal that of the actual dryness in the desert soil. If it were possible to obtain a non-toxic solution sufficiently concentrated, we might, on physical grounds, expect to obtain the same sort of response it plants growing therein as occurs in the nearly dry, non-saline soil.

Forms in which sodium cholride does not accumulate thrive likewise in the salt swamps, a good example being the date palm (*Phoenix*), which there develops much higher pressure than in the non-saline irrigated land.

Our author brings out clearly the point (of which I was long ago convinced by superficial observations on the dunes of Lake Michigan) that the sand dune is to be considered as a *relatively moist* substratum. The dunes of Biskra possess a more luxriant vegetation than that of the surrounding desert and upon them occur, together with generally distributed species many forms which are rare or wanting elsewhere. I have repeatedly made a similar observation on the sand dunes of the Salton Basin (California), a region which seems quite closely to resemble that of Biskra. I have also noted that generally distributed desert plants often attain a more luxriant growth upon some of these Salton dunes than upon the stony loam of the basin floor. *

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*It must be remarked in this connection that such desert dunes sometimes owe their origin to springs or moist soil. In such cases the blowing sand is more or less permanently

Many of the dune plants tested by Fitting possessed an osmotic pressure markedly lower than that of the same forms in the mountains and boulder desert. Fitting concludes, "The lower pressure upon the sand seems to indicate that the water supply in the sand is less limited than in other dry desert soils." (p. 251). He also calls attention to the low resistance offered by sand to absorption by roots, and cites the rapid downward penetration of rainwater in such soil and to the possibility of extensive root growth therein.

Fitting repeatedly asserts that the power to develop such high pressures as he has demonstrated is a purposeful adaptation for living in dry soils! *

In physical terms, *if we assume* that the movement of water from soil to plant depends upon the gradient of diffusion tension which exists between the soil films, on the one hand, and the solutions within the roots, on the other; it follows that the lower the internal diffusion tension, the drier will be the soil when equilibrium is reached. Vapor pressure is proportional to diffusion tension (is, indeed, a special case of this) and we have merely to consider that the vapor pressure of the internal solutions decreases as their osmotic concentration rises, while the vapor tension of the soil moisture films decreases rapidly as as the films becomes more tenuous. Thus we have an attraction of the cell sap of roots, for water, opposed by an attraction of the soil, the former force depending upon the osmotic concentration of the sap and the latter upon the thickness and arrangement, as well as upon the osmotic concentration of the soil moisture films. It is from these con

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arrested by being moistened and thus a dune is built up. See MacDougal, D. T. Publication 99 of the Carnegie Institution, 1908, p. 3[illegible]. Such a dune may attain a height of several meters, being mainly held in place by stems and roots of thrifty plants, which derive moisture from below and suggest to the eye the presence of a continuous supply of water. Dunes of this sort, well covered with vegetation, often occur where the soil is apt to be moist for the longest periods, as along the margin of an out cropping drainage stratum, and the accumulated sand should act as a very perfect mulch to conserve the natural soil moisture of such localities. Thus the more vigorous plant growth here may be largely due to the sand mulch. Whether or not these considerations may have any bearing upon the nature of the dunes and dune vegetation in the vicinity of Biskra I am unable to surmise. That there are out cropping drainage strata in that vicinity is clear from the existence of the original oasis itself, the springs of Hammam Salahin, etc.

* "Man wird diese Befähigung als äusserst zweckmässig betrachten müssen, um auf sehr trockenem Boden gedeihen zu können." (p. 246). To my mind nothing at all is gained and the general muddle of ecology is greatly augumented by such methods af statement. It were fully as well to anthropomorphose the soil as well as the plant, and to hold that extreme dryness is a *soil adaptation* by which the Sahara soil better succeeds in preserving itself largely untrammelled by vegetation!

siderations (p. 218) that Fitting formulated the experimental project which he has so he successfully carried out.

The supposition that high pressures in the leaves indicate correspondingly great powers of absorption from dry soils it the form in which it is advanced by our author, *depends upon the assumption that these pressures are accompanied by similarly high pressures in the root cells* (which has been rendered highly probable by Stange—*loc. cit.*—,but which needs more thorough study) *and also upon the assumption that the entrance of water into the root is a function of the osmotic-capillary or osmotic-adsorption* relation described in the last paragraph. This last assumption is by no means an established fact; we know as yet practically nothing of the energy relations of water absorption from non-saturated soils, and the work of Dixon on the tensile strength of minute water columns [*] renders it apparently possible that ''osmotic pressure does not indeed play the important part in water absorption which has hitherto been assigned to it.'' [*] This one of the two alternatives presented by my experiments with soil-osmometers meets with no approval from Fitting (p. 219). I must, however, remain undecided in regard to this whole question of the physics of root absorption till more quantitative information is at hand (the question will be referred to again below), but agree thoroughly with Fitting that ''this question can be answered by the research-methods of physical chemistry'' (p. 219), and that the osmometer method described in Publication 50 ''might have been replaced by a better'' (p. 220). But, after several years of experimental contact with this problem of the resistance offered by the soil to root absorption, I am unable to agree with him that a satisfactory method may be attained ''without difficulty'(''wohl unschwer,'' p. 220). This is perhaps the most important problem that confronts the plant physicist today, and is well worthy of careful study.

One rather fundamental aspect of the relation between soil and roots, at least so far as my own studies in this connection have led me, is one that seems completely to have escaped the notice of our author. Whatever may be the nature of the forces which determine whether or not water will migrate into root cells from an adjacent layer of nearly dry soil, the *maintenance* of such movement must depend, not merely on the initial gradient of the forces involved, but upon the relation between the rate of removal of moisture from the absording cell membranes into the plant interior and the possible rate of water movement through the soil. Thus,if the conditions were such (as they must often be in arid regions) that moisture were more rapidly absorbed from the soil layer immediately adjacent to the absorbing cells than the soil conditions would allow it to be replaced from more remote layers, it is obvious that the absorbing surfaces of the plant must soon become surrounded by a layer of soil too dry to give up any more moisture. Thus absorption would be checked, although there might be large amounts of water in the soil as a whole. The possible rate of moisture movement through the soil and the relations of this rate to the physical properties of the latter must ever be an important factor in the control of plant absorption from nearly-dry soils,

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[*] Summarily presented in this paper, ''Transpiration and the Ascent of Sap,'' Prog Rei Bot. 3 1 66. 1909.

[†] Publication 50 of the Carnegie Institution, 1906, p. 21.

At several points in the paper Fitting expresses the idea though it is nowhere strongly emphasized, that a high osmotic concentration of the foliar cell sap must act directly to retard transpiration. This must be undoubtedly true, on physicochemical grounds, but the *amount* of such retardation cannot be large enough to exercise a primary, or even a great, influence upon the success or failure of plant forms. I have elsewhere [*] discussed certain aspects of this question, and shall reserve its fuller consideration for a future paper, but may state here that a solution of the strength of the highest concentrations found by Fitting in the foliar cell sap of desert plants (something over 100 atsmospheres of osmotic pressure) possesses a vapor tension less than 10 % below that of pure water, and should therefore evaporate more than 90 % as rapidly. It is thus clear that no great ecological importance is to be attributed directly to the checking of water loss by low vapor tension of the foliar solutions.[†] What may be the *indi*

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[*] Livingston, B. E., "Relation of the Daily March of Transpiration to Variations in the Water Content of Foliage Leaves." Bot. Gaz. In press.

[†] This has been clearly shown by Drabble and Drabble, for a humid region. See Drabble, E. and Drabble, H., The relation between the osmotic strength of cell sap in plants and their physical environment. Bio-chem. Jour. 2: 117-132. 1907.

rect effects of such high concentrations as Fitting has demonstrated need not be considered here.

The very moderate lowering (about 10 %) of the vapor tension in the presence of enough solute to yield an osmotic pressure of 100 or more atmospheres renders it improbable that the concentration of the cell sap of roots should play a direct role in determining the lower limit of available soil moisture. When the roots are bathed in a solution (as in the case of the salt swamps), and uot merely wetted by *imbibed* or *adsorbed* moisture (covered by a capillary film), *then* the internal osmotic pressure should be directly opposed to the pressure of the surrounding solution, and it seems quite possible that high sap concentration may accelerate water entrance. At any rate, such osmotic pressures in submerged roots must play an important role in maintaining cell turgidity, which appears to be very necessary for root absorption. Until more is known of the quantitative relations between the energy of surface tension, imbibition, etc., and that of vapor tension and osmotic pressure, as these forms of energy are manifest in the plant and its environment, the whole problem here touched upon must rest in abeyance.

An interesting suggestion is made by Fitting (p. 257-8) to the effect that transpiration water in certain desert forms may possibly, during the driest seasons of the year, be derived from the decomposition of carbohydrates, etc., through the process of respiration. I am not aware that this has ever been suggested before, and the idea seems well worthy of an investition. It is thus rendered paradoxically possible that there may sometimes occur a continuous loss of water from an organ or tissue, which, upon being tested, exhibits almost none of this liquid and which receives no moisture from without! Our author supposes that this consideraiton may apply to forms which possess accumulated carbohydrates, as in tubers and enlarged roots.

Fitting's statement (p. 265) that "from a purely physical standpoint, all the hinderances to water supply in a saline soil seem to be overcome when the plants growing therein,by an increased cell sap concentration, maintain a concentration gradient corresponding to that in a non-saline soil,'' seems to apply only to saline soils whose solutes are *not toxic to the plants*. Of course a chemically poisonous substance existing in the soil in comparatively low concentration may produce apparently the same effect upon plants growing therein (dwarfing, loss of leaves with increasing evaporating power of the air or with increasing sunshine intensity, etc.,) as does a nontoxic salt at a much higher concentration. *

As I have long since pointed out, † the stimulating effect produced by the toxic materials of an unproductive soil upon plants growing therein seems to be primarily due to a more or less complete inhibition of the formation of laterals and an early senescence of the primary roots, rendering them very poor absorbers of water. Such phenomena probably occur also in the acid humus soils ‡ which, since Schimper's time, have been called ''physiologically dry.'' These considerations, while not of the quantitative nature which Fitting quite rightly desires as a basis for our theory of physiological aridity, do, it seems to me, render the general problem somewhat clearer than our author's sentences would indicate. There are apparently two very distinct kinds of physiologically dry substrata. In one of these the resistance to water absorption by plants is due simply to a high osmotic concentration of the soil solution. With this form Fitting has had to deal in his work upon the Biskra salt-spots. In the second kind, the osmotic pressure of the soil solution is not markedly higher (indeed it is sometimes actually somewhat lower**) than that in non-arid soils, but there are here present small amounts of chemically toxic materials. In the presence of these substances root development is markedly abnormal *and the abnormal root structures may hinder the entrance of water from the soil.* Thus, we may conclude that in the first variety of physiologically arid soils the hindrance to water entrance is due to lack of the resquite osmotic gradient, while in the second it is probably due to properties of the absorbing surfaces or osmotic membranes, the resquisite gradient, however, being present.

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*The reader may refer, for examples, to the interesting paper of Kanda and of Jensen upon the toxic limits for plant activity in regard to salts of copper, zinc, nickel, etc. in the soil.—Kanda M., Studien über die Reizwirkung einiger Metallsalze auf das Wachstum höherer Pflanzen. Jour. Coll. Sci. Imp. Univ. Tokyo 19. Art. 13. pp. 1–37. 1904, and Jensen, G. H. Toxic limits and stimulation effects of some salts and poisons on wheat. Bot. Gaz. 43: 11–44. 1907.

†Livingston, B. E., Note on the relation between growth of roots and tops in wheat. Bot. Gaz. 41: 139–143. 1906. See also Schreiner, O., Some effects of a harmful organic soil constituent. Bot. Gaz. 50: 161–181. 1910.

‡Livingston, B. E., Physiological properties of bog water. Bot. Gaz. 39: 348–355. 1905. Dachnowski, A., Physiologically arid habitats and drought resistance in plants. Bot. Gaz. 49: 325–339. 1910.

**Livingston, B. E., Physical properties of bog water. Bot. Gaz., 37: 383–385. 1904.

Numerous fundamentally important considerations in Fitting's highly admirable, though somewhat loosely presented, researches, have received no mention at all in the present paper; whoever is interested in the water relations of plants must study the original, the author of which is to be congratulated upon the success and thoroughness with which he has carried out, under rather difficult conditions, what will long remain a fundamental pioneer research not only for desert ecology but also for ecology in general and for scientific agriculture.

The Johns Hopkins University.

STUDIES IN SOIL PHYSICS, IV. *

THE PHYSICAL CONSTANTS OF SOILS.

E. E. FREE.

Soil science has begun its introduction to the quantitative, and its votaries are newly but rapidly learning to "observe" a little less and to measure a little more and a little more accurately. It is a much needed change—one of great promise and already of some fruition, but perhaps its greatest service has been to call attention to the weaknesses of present methods and the inadequacy of present tools. There are so few measurements that can be applied to problems of the soil. In soil physics, for instance, we are accustomed to refer the various physical behaviors of the soil to a hypothetical "physical nature" or "physical character" which is supposed to be fundamental and causal of all more superfical properties and behaviors. Whether we call this physical character the "nature and numbers of the constituent particles" or whether we define it more exactly (and less luminously) as the expression of the possible ranges of variation of all the physical properties, or whether we shirk definition altogether, is unimportant. Physical character remains something which cannot be measured directly and which we must examine, if we examine it at all, by devious and indirect paths. Nevertheless some quantitative expression or indication of physical character seems quite necessary to further advance of the science. The actual, momentary physical condition of a soil is indeed susceptible of some quantitative examination and perhaps of sufficiently accurate measurement, but this does not touch the core of the matter It is necessary to know, not what the soil is temporarily like, but what it can be like—not its exhibited properties but its potential properties. Within limits physical condition is under human control; physical character is very seldom so, and it is physical character that we most need to learn to know. This is—physically—the fundamental property of soils.

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But physical character is not even accurately decipherable let alone measurable. It is probably far too complex ever to be measured by one process or in one unit. We must fall back upon a subterfuge. If we cannot measure the thing itself we must select something dependent upon it and measure that We want some measurement which will indicate, if it does not completly express, the more fundamental physical character The electrical engineer has certain curves which express the behavior and cabapilities of a dynamo,which curves he calls the "characteristics" of the machine. We want a physical "characteristic" of the soil. I have spoken, and shall speak, of this "characteristic" as a "physical constant" for it must bear a constant relation to physical character and must be, for any one soil, fully constant and reproducible.

Of the qualities which must be possessed by this constant the first is simply this constancy of relation to the ultimate physical character of the soil, regardless of the condition it may happen to be in at the moment. Our constant must not be affected, for instance, by accidental variations in the treatment of the sample or by its recent history. Secondly, the constant must vary closely and in rigid correspondence with changes in the physical character and its variations must be of sufficient magnitude to enable the detection, through them, of important differences in this physical character. Thirdly the constant must be measurable with fair ease and accuracy. If the constant be numerically simple and if its relations to other physical properties and to the physical character be rational ones, so much the better. If, however, numerical complexity cannot be avoided and if the needed correlations must necessarily be obtained empirically, we must needs make the best of it, and the fault will not be fatal.

Such a constant would be of incalulable value not only in purely scientific soil investigation, but also in practical agriculture. It would place the classification and comparison of soils on a far better basis than any now available, and it is not too much to hope that correlations might be obtained with fertility itself, at least in so far as this very complex quantity is related to the physical nature of the soil and to its physical properties. This need has not gone unappreciated. There have been many and various suggestions of possible physical constants, and in particular the mechanical analysis has been much used and has been long enjoyed (wrongly, as I believe) some reputation for adequacy.

Mechanical Analysis. This mechanical analysis, and the mechanical composition which it appropriately expresses, have been discussed in the first paper of this series and need not now be reviewed. Nor need anything be said concerning the various methods used or suggested for the separation of the soil particles into groups of the various sizes or concerning the different systems of limits between these groups. * For details on these matters the reader is referred to the textbooks of agricultural analysis. The merits and demerits of the mechanical analysis as a soil constant depend upon inherent characteristics which have little or nothing to do with the details of manipulation or the form of the results. And, as I expect to be critical, let me say first that mechanical analysis is by no means useless nor to be belittled as a means of soil investigation. It has been much used and, on the whole, pretty successfully, and we now are in possession of many thousand analyses and of at least some beginnings toward correlations with the physical properties observed in the field. But it can hardly be considered as fully satisfying the requirements which we have seen to be essential for the needed constant, and the sooner we cease believing that it does, and begin to examine critically its usefulnesses and its limitations, the sooner shall we be able, not only to find a better constant, but to attain to a rational use of the mechanical analysis itself.

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*Studies in Soil Physics. I, Plant World, 14: 31. 1911.

In the fisrt place it must be remembered that the whole business is purely empirical. The mechanical composition of a soil doubtless determines its physical properties but the laws according to which the determination is affected are still unknown and quantitative correlations, if they exist, remain undiscovered. We can do no more than to examine the external properties of soils and determine the corresponding mechanical analyses in order that, by the gradual accumulation of such comparative data, we can come more and more to say that a soil of a certain mechanical analysis will probably possess certain properties—which properties we have learned by experience usually belong to soils giving that, or nearly that, analysis.

However, this empirical character of the process is unfortunate mainly because it makes impossible exterpolation or wide interpolation and hence requires that over the whole field of possible mechanical compositions correlations with observed properties be obtained by actual experiment. Except for the extra labor thus required it makes no great difference whether the process and its correlations be empirical or not. The correlations of phosphorous content with breaking strength in steels are useful enough for all that they are empirical.

The main trouble with mechanical analysis and the main reason why it can never be satisfactory as a physical soil constant lies in the complexity of the final "constant" to which it leads. The mechanical analysis must be expressed as a series of unrelated quantities—the percentages of the particles in the various groups. It can never be expressed in any one unit but must always refer to several—one for each group in the series. And there is no common denominator. It is impossible, for instance, to arrange soils in the "order of their mechanical composition" as one would arrange minerals in the order of their specific gravity or wires in order of their electrical conductivity. This makes mechanical analysis a very hard thing to think with. The mind must not carry one quantity but several and compare them jointly and severally (but all at the same time)with that external property whose correlation with mechanical composition is being sought. The requisite degree of mental dexterity is not common. Furthermore the lack of unity in the expression of mechanical analysis precludes the application to it of curves and of graphic methods generally—a loss,the great proportions of which can be partially appreciated by recalling the immense service which these methods have rendered in other branches of physical science.

Closely related to this fault of disunity in expression is the error introduced by the fact that the particles within the limits of any one of the size groups are necessarily lumped together in the result. From the mechanical analysis we learn merely that so much material is within the size limits of a given group. We do not know whether the particles comprising it are of sizes mainly near the upper limit or are mainly near the lower, or whether they are more or less uniformly distributed among the intermediate sizes. With finer soils this error is of great practical importance. For instance, according to the usual American system, all particles below .005mm. in diameter are classed as "clay" though in one soil this "clay" may consist mainly of particles just inside the limit, (say .002 mm. to .004 mm. in diameter) while in another it is composed largely of particles so small as to approach the colloidal state. The physical properties of two such soils are radically different but their mechanical analyses are exactly the same so long as the same quantity of material lies below the .005 mm. limit. Exactly this case is of such frequent occurrence in practice that various attempts have been made to devise methods for the determination of the "colloidal clay" as an adjunct to the ordinary mechanical analysis. These methods have not been particularly successful, but even if they were the solution of the difficulty would be but partial. It would amount to no more than the addition to our present system of size limits of another one below our present lowest. Within the new groups thus established the difficulty would be nearly as great as before, and the slight improvement in accuracy which might be expected to ensue would be attained at the cost of an additional operation (and a very troublesome one) with a consequent increase in time and labor expended. The error could be made insignificant only by the employment of a very large number of groups and the determination of the amounts of material lying within each. Obviously, such a large number of groups means a multiplicity of analytical operations and an expensive and laborous method. Any system of analysis with few enough groups to be practicable is going to give at best only a somewhat rough approximation of the real mechanical composition. Furthermore, in the place where the greatest practical errors occur, namely in the finer particles, our laboratory methods for the separations of are hardly accurate enough for any greatly closer spacing of the limits and these methods are probably not susceptible of much improvement. Our present systems of mechanical analysis are about as good as we can hope to get.*

There is still a third major error in the mechanical analysis, that introduced by the variations in the shapes of the soil particles. Shape and degree of roughness have various effects upon the physical properties and still other and unrelated effects upon the mechanical analysis. Indeed, since some of the group separations are made by sieving, and some by water elutriation, the shape effects will be different on the different groups of the same sample. Ordinarily, perhaps, these shape effects are not particularly important since soil particles are usually roughly spherical in form and of about the same shape-character in all soils. But in special cases the error is by no negligible. A very micaceous soil, for instance, has very different physical properties from one of the same mechanical analysis but composed of particles which are mainly spheres insteads of disks.

These three errors of the mechanical analysis are all incorrigible. They may be denoted as (1) disunity of expression; (2) failure to express conditions within the limits of the individual groups; and (3) failure to take account of variations in the shapes of the particles. All are inherent in the nature of the process and if we are to use at all the mechanical analysis as a soil "constant" it will be in spite of these errors and not because they have been removed. In the process as at present conducted there are indeed other errors: the failure to take account of the permanent and semi-permanent flocculations; the errors caused by organic matter and by dissolved salts; the variations caused by the different methods of sieving and of elutriation, etc. But these errors are not inherent. They can probably be removed if it seems useful to do so. The three previously discussed are the crucial ones, and if mechanical analysis is ever replaced by something else it will be on their account.

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*Unless air elutriation for clays can be rendered practicable, and this seems very unlikely.

The Surface Constants. Of course these imperfections of the mechanical analysis have not been suddenly and recently discovered. They have long been appreciated and many suggestions have been made looking toward their avoidance or the substitution of another and more satisfactory physical constant. First of these, chronologically, was probably the suggestion to use as such a constant the total amount of surface of all the particles in a certain weight (or volume) of soil. Indeed it was early suggested that the internal surface (as this is called) might be determined from the mechanical analysis itself and that the inconveniences due to the disunity of expression of the latter might thus be elimated. If the mechanical analysis were reduced to, or expressed as, a surface it could be expressed in one unit. Unfortunately, however, the lack of knowledge of conditions within the group limits and of the shapes of the particles make it impossible successfully to determine the internal surface of the soil from the mechanical analysis and if this surface is to be used as a constant it must be otherwise measured Direct measurement being obviously out of the question, it is necessary to find something dependent on the surface and to measure that. This something has been found in the heat of wetting.

When a dry powder is placed in water a considerable quantity of heat is evolved and the quantity of this heat varies directly with the total internal surface of the powder and probably in close proportionality thereto.* This fact, long known to physicists, has been applied by Mitscherlich to the soil. Using a Bunsen ice calorimeter and very ingenious devices for introducing and wetting the dried soil he is able to obtain values which are concordant and reproducible for any one soil and which vary from soil to soil with variations in the physical character. Of course the correlation of the heat of wetting with the general physical properties is just as empirical as was the correlation of the mechanical analysis therewith, but this as before is comparatively unimportant. The heat of wetting is a single quantity expressible in a single unit; it is free from the shape error and the group error that beset the mechanical analysis; and it is probably closely and rigidly related to the fundamnetal physical character (as distinguished from physical condition) of the soil. As a soil constant however, it is open to two errors; (1) the effects due to the heats of solution and dilution of the soluble material present in the soil; and (2) the effects of the organic residues, largely the remains of plants. The former is probably unimportant. In all ordinary soils the soluble salts are so small in total quantity and so nearly the same in nature and amount that their effect on the heat of wetting is probably almost constant, especially if the same relative amounts of soil and water be employed in each case. The effect of the organic materials is less easily predicted. They may behave similarly to the inorganic materials, or they may not. They are known to effect both the general physical behavior of the soil and the heat of wetting. If they affect both in the same way and ratio, the exact forms of the relations are unimportant—the heat of wetting is nevertheless a true representation of physical character. If the effects on physical character and on heat of wetting are diverse the latter will fail to properly indicate the former when much organic matter is present. More complete elucidation of this matter must await further experiment. In any event the heat of wetting seems to offer much promise as a substitute for, complement to, mechanical analysis, and it has actually been so used by Mitscherlich and his co-workers, apparently with satisfactory results.

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* For the purely physical side of this problem and for references to the literature see Patten, — Trans. Amer. Electrochem, Soc. 11: 387-407 (1907)

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*For details see his Bodenkunde für Land und Forstwirte 1905. P. 51-70

Besides the heat of wetting there have been proposed two methods of measuring the internal surface of the soil. One of these is the measurement of the amount of a given dye d-sorbed from solution by a given quantity of soil. This has proven of some utility in the classification of fine clays for porcelain manufacture and similar uses. Otherwise it has never been, nor is likely to be, of any importance. The third and last internal surface method is the determination of the hygroscopicity or the percentage of water absorbed by dry soil from a saturated atmosphere. Essentially this is a measurement of the vapor pressure of the water in the soil interspaces and,as no experiments have ever been made specifically on this point,no one knows whether this vapor pressure depends directly upon the nature of the soil or not. Probably it does not and probably the determination of the hygroscopicity has neither theoretical warrant nor practical utility. At any rate the case for it is still unproven.

The Water Retentivity Methods. Both the mechanical analysis and the internal surface methods attempt to get at, directly or indirectly, some fundamental, inherent property of the soil, with which property its general physical nature is supposed to be in close relation, This is perhaps not entirely necessary. If, for instance, there were some constant expressing the physical relation of the soil to water and from which the water-holding and water-moving properties of the soil could be deduced, this would probably be all that is needed. Water relations are so much more important than other physical properties that, with them known, we could afford to forgo the rest. It is probable, however, that any constant expressing satisfactorily the water relations of a soil would express pretty nearly other physical properties as well. All are probably dependant upon the same, more fundamental, characters.

Of the many suggestions towards some such "water constant" the most elaborated is the method of Briggs and McLean for the determination of the "water equivalent."* This may be defined as the percentage of water which will remain in a soil when it is so whirled in a centifuge as to be subjected to a force of definite and considerable intensity. Essentially this is a draining under a force acting like gravity but many times as strongly. With the same centrifuge running at the same speed, or with a proper ratio of speed and diameter of drum whatever these may be, the conditions are closely reproducible and it is believed that the percentages of retained water thus measured stand in close and pretty rigid relation to the physical nature of the soil and especial to its behavior towards water. The exact forms of these relations are not known, and, as before, all correlations are purely empirical. Furthermore, the method itself is empirical and the numbers obtained on the given soil types will not vary, not only in numerical value but also in relation to each other, with variations in the intensity of the centrifugal force. The amount of water retained by any given soil varies with the centrifugal force applied, and as the force becomes more and more intense, more and more water is extracted, but, as usual, equal increments of force produce progressively decreasing decrements of water content. The amount of water retained falls (as the force is increased) toward a limiting, asymptotic value below which still further increases of force produce very little extraction of water. Both the actual percentage of water corresponding to this asymptotic condition and the intensity of the force by which it can be obtained vary with the physical character of the soil. In sands it is low and easily attained, in clays it is higher and is attained only with greater forces. Now the forces usually employed in determining the water equivalent are intermediate between those competent to produce the asymptotic extraction in sands and those necessary to produce it in clays. Consequently the values thus obtained for the retentivity of different soil types are not comparable with each other, being made by methods not physically alike. The water equivalent, thus determined, is not really a physical constant but merely an empirical determination made by an arbitrary method and not comparable in any sense with similar determinations made by slightly varied methods.

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*Bulletin 45 Bureau of Soils, U. S. Department of Agriculture. 1907.

As will be seen later this condition is not insusceptible of improvement, but even if it were, the practical usefulness of the water equivalent would not necessarily disappear. It could still furnish a means of soil classification and of the correlation of physical nature and field properties, provided only that the water equivalent of any given soil type be characteristic of that type and constantly given by it. Empirical as it is, such a "constant" is better than mechanical analysis and if nothing better can be devised it is doubtless destined to a large usefulness in future soil investigation. As yet, however, it has been very little used or studied.

The Critical Moisture Content. The foregoing include all the "constants" so far used or prominently suggested. There remains, however, one other possibility, as yet nearly unnoted but perhaps the best of all. In the first and second papers of this series there were discussed the relations of the film water to soil structure and to water movement in the soil, and there was noted the discovery by Cameron and Gallagher* of the "critical moisture content" as a percentage of contained water, definite and constant for each soil, at which content all the physical properties of the soil are either at a maximum or a minimum.

It will be recalled that this critical moisture content is believed to correspond to the point of maximum efficiency of the forces resident on the surfaces of the water films between the soil particles. If this be true here is a soil constant worth while. It is closely (and nearly exclusively) related to the physical character of the soil (since the water-film-system is so related); its variations with this physical character are wide enough to be easily measurable; it is expressed simply and in a single unit; and, best of all, its relation to the physical character and to other physical properties is real and rational. It is a real property of the soil —a constant which means something. It may be determined in a dozen different ways and neither the accidents of the determination, the history of the sample, nor the personality of the experimentor will affect its value, Unfortunately it has one very serious disadvantage—its determination is exceedingly tedious, laborious and costly. * So much is this the case that the critical moisture content, as at present determined, is entirely out of the question as a generally useful constant and can find utility only in the most extensive scientific researches where labor and expense are minor considerations. Whether this condition is hopeless, we shall see presently.

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*Bulletin 50 Bureau of Soils, U. S. Department of Agriculture, 1907.

*For the actual methods the reader is referred to Bulletin 50, Bureau of Soils, U. S. Department of Agriculture, above quoted

Conclusions. In the preceding pages there have been discussed four "constants" which have been used or suggested: (1) the mechanical analysis; (2) the heat of wetting; (3) the moisture equivalent; and (4) the critical moisture content. Of these the water equivalent is purely and entirely empirical both in method of determination and in its correlations with other properties. It does not attempt to measure any constant property of the soil, but only the reaction of the soil to a set of arbitrarily chosen conditions. The mechanical analysis is similarly empirical in its correlations with other properties, but not so much so in its methods. The mechanical composition is a definite and constant property of the soil and is so far as the mechanical analysis actually measures this composition, in so far is it a soil constant. But this is not very far. Because of the group error above discussed the mechanical analysis is never more than a more or less accurate approximation to the real mechanical composition, and it is usually less accurate rather than more. Furthermore the mechanical analysis is expressed in complex and distinctly unserviceable numbers. The heat of wetting is a little better off. It is similarly empirical in correlation and similarly rational in determination (since it tries to measure a real soil property—the internal surface) It surpasses the mechanical analysis however, in that it actually measures the things which it aims to measure and does it pretty accurately, even if not directly nor in absolute figures. But from the logical viewpoint the critical moisture content is the best of all, since it is rational not only in method of determination but also in some of its correlations with other properties. In relation to physical condition the value of the critical moisture content means something immediately, directly, and in itself regardless of what further correlations may be established empirically.

But logical correctness is not the whole of the matter. Practical utility is the essential criterion and here the critical moisture content (because of the difficulty of its determination) is woefully lacking. Taking all matters into account one must conclude that the heat of wetting is the best of the four. It measures a real soil property with sufficient accuracy and sufficient ease and the empirical character of the correlations between it and field properties is a fault which seems more serious than it is.

But the heat of wetting is by no means perfect. It is perhaps the best we have, but it does not follow that it is the best we can get,and further search is well worth the effort. I am convinced that the most promising line for such search to follow is in the devising of a new and practicable method for the determination of the critical motsiure content and there is at least one indication of what such a method might be. In the discussion of the water equivalent it was pointed out that, as the centrifugal force is increased, the percentage of water retained falls toward a limiting or asymptotic value which varies with the physical character of the soil. Now this limiting retentivity, or asymptotic water equivalent, is very probably a real property of the soil and just as much a soil constant as is the critical moisture content. Furthermore, in the few cases so far studied, the critical moisture content and this limiting water equivalent seem to be not only related but identical. So little experimental work has been done that it is not yet possible to say definitely that this so, but if it is, the whole situation is simplified. We need but to determine the water equivalent with a centrifugal force high enough to attain the asymptotic extraction in all types of soil and—presto—we have attained the critical moisture content. The problem would be solved and there would be to hand a more capable tool than any which soil investigation has yet possessed.

The vision is entrancing but as yet it is only a vision, and it behooves us to set rapidly to work upon such experimentation as will prove this vision for mirage or for truth. We need more studies of the critical moisture content, of the water equivalent, and, especially of the relations of the two. Aside from its organic relations this is (to my mind) the most vital and the most urgent field of soil physics today. The most important thing about the physical soil constant is the search for it.

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Washington, D. C.

BOOKS AND CURRENT LITERATURE.

TRANSPIRATION IN SALT-MARSH PLANTS.—Quantitative and analytic studies of plant transpiration are becoming frequent. The paper before me, by E. Marion Delf, * is a well-conducted piece of work of the newer type, on water loss from such halophytic forms as *Salicornia* and *Suaeda*. In the opening paragraph is to be read a bit of the most egregious teleology which it has been my misfortune recently to come upon. The passage reads that halophytes "are unable to absorb water freely from the soil, owing to the danger of thereby bringing into the tissues injurious amounts of salts. Since the absorption is thus limited, the transpiration must be also diminished," etc. The idea is attributed to Schimper and it is stated to have been accepted by Pfeffer and Jost. Gibson's translation of Jost has it in a form nearly as poetical as the one quoted, but I do not find it thus in Ewart's translation of Pfeffer. Perhaps it may be a long time before current physiological literature may be free from teleology, but the time for actual personification of plants is surely past, and to suppose them to avoid a danger is closely approaching that. The physiological dryness of substrata is in crying need of much more study than it has yet received.

To obtain the area of the little boat shaped leaves of *Suaeda* ten leaves were laid side by side upon the coordinate paper, a tracing made around the whole, and the squares counted in the usual way. The use of the planimeter, which I have found accurate and very much more expeditious than the method of counted squares, was not resorted to. An ingenious method was devised for checking the determinations of area obtained by calculation in the case of the regular stems of *Salicornia*. This consists in coating the shoot with a celloidin film, slitting the latter along one side, and removing, after which the method of squared paper is used. The film must not be allowed to dry too thoroughly.

The initial transpiration rates of cut shoots of the mesophytic *Mecurialis annua*, green and crimson *Salicornia* and *Suaeda*, all side by side in the open, were determined by weighing. For the first 150 minutes the *Mercurialis* shoots lost 0.173 g. per hour, per 100 sq. cm. of area. For the first 90 minutes the corresponding rate for *Suaeda* was 0.350 g. The last named plant exhibited the highest rate of water loss per unit area, while *Mercurialis* showed the lowest. The author determined the "degree of succulence" of each plant as the water content per 100 sq. cm.; for *Mercurialis* it was 0.95 g., for *Salicornia* 6.5 and 6.1 g., and for *Suaeda* 10.0 g. Thus the *highest* degree of succulence is accompanied by the *highest* transpiration rate per unit area! Under a bell-jar with humidity about 56 %, the *relative transpiration,* (related to evaporation from a water surface, *) of cut shoots of *Salicornia* was 0.32 and of *Vicia cracca,* 0.26 for the first 20 minutes. This means the unit area of *Salicornia* lost 32 %,of *Vicia* 26 % as much water as an equal area of free water surface Here again the succulent loses moisture more readily, *per unit of area exposed,* than does the mesphyte. Additional evidence of a similar nature is presented by the author, who also points out that, while other succulents (*e. g. Sedum*) thrive in rather dry air, if plenty of water is applied to the roots. *Salicornia* under such conditions does not absorb water through the roots as rapidly as this is lost by transpiration. It thus appears that this form of *Salicornia* (*S. annua*), at least, would not succeed under conditions of intense evaporation, even though its roots were in salt-marsh water. But the air which usually bathes the stems is of high humidity, and furthermore,as is shown in this article the green surfaces absorb water rapidly when submerged, though the absorptive process is not nearly so rapid as that of transpiration in moist air, surface for surface. But little absorption takes place from a nearly saturated atmosphere.

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*Delf E. Marion. Transpiration and behavior of stomata in halophytes. Ann. Bot 25 485 505. 1911.

Determinations were made of the number, size and distribution of stomata in several plants. It appears that, in *Salicornia* and *Aster tripolium* these organs open and close with light and darkness, while the plant is young, but that with the coming of the flowering time this power of movement is lost and the pores remain permanently closed.

It is to be hoped that the author may continue this work and determine the physical influence of stomatal movements upon the rate of water loss in such halophytes.—BURTON E. LIVINGSTON.

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*Livingston, B E., The relation of desert plants to soil moisture and to evaporation. Publication 50 of the Carnegie Institution 1906.

NOTES AND COMMENT.

The report of the fifth annual meeting of the Botanical Society of America contains a list of members and associates from which it appears that the society now has 98 members and 62 associates members,the latter presumably being conditionally eligible for full membership. These combined lists include the names of more than 75 professors, associate and assistant professors of botany (including a very few in forestry and plant pathology); the remaining names, approximately 85 in number, are of investigators, directors of laboratories, and others, practically all of whom are now or have been until recently actively engaged in botanical work. The constitution of the Society provides that "Candidates for membership must be actively identified with botanical work, and must show special ability in original research, as indicated by published papers or merit."

A single generation ago a society of this character and of such requirements for membership, if it could have been organized at all in the United States, would hardly have had a dozen members. In the late seventies very few institutions in the country made any attempt to maintain a botanical department. Harvard was the best equipped, and while Dr. Gray, relieved of teaching, was devoting himself to the herbarium and the Flora, his assistant professors, Drs. Farlow and Goodale, were offering almost the first and only opportunity in plant physiology and cryptogamic botany that has been known in America. At Yale Professor Eaton set his students to working on mosses, while he worked on his fern books and built up his fine herbarium. Cornell had organized a more comprehensive course of botantical instruction with Professor Prentiss at its head, and in Michigan Professor Beal at the Agricultural College was training students in his own unique way and collecting material for his book on grasses. Other lights were rising here and there—among others Britton, Coulter and Bessey, and here and there a single worker like Peck in New York or Vasey in Washington pursued his lonely way as a special student of fungi or grasses or some other group of plants. Young men were not usually encouraged to choose botany as a specialty unless they had independent resources. The future of the science in America was, to say the least, problematical. No one could have predicted the remarkable development of botany both as a pure science and in its practical application that has has been seen in the last third of a century.

Still the leading teachers and botanical investigators of the country are not satisfied, and doubtedless this is well, though one cannot help wondering what he should see if their ideals were fully realized. A resolution adopted by the botanical Society of America the Bureau of Plant Industry alleges that the Bureau has suffered severe losses of scientific men during recent years and calls for the Council of the American Association for the Advancement of Science to investigate and recommend such improvements as promise increased efficiency; and the heart to heart talk at the Minneapolis meeting of a group of veteran botanical teachers, through less lugubrious than sometimes happens, recalls the words spoken by a great educator to his embryo teachers "Well, they will learn something in spite of you." Despite all of our shortcomings the botantists of America, nearly all of whom have been trained in the United States, constitute such a body of men and women as cannot possibly be duplicated in any other land, and their work, both in teaching and in research, constitutes a chapter in the history of botany that by no means justifies a pessimistic outlook.—V. M. S.

Volume 14 Number 8

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

AUGUST, 1911

FRONDESCENCE AND FASCIATION.*

BY HENRI HUS.

It is but natural that forms which show striking morphological changes should attract our attention more readily than do others, color variations perhaps excepted. Thus it required no great effort to find the abnormal dandelion shown in fig. 1. It was observed in the spring of 1910 at Ann Arbor, Mich., on a plant growing in an empty lot in a spot level with and within a few inches of the sidewalk. During 1909, specimens of both *Taraxacum officinale* and *T. erythrospermum* growing here had shown numerous fasciations, especially during the early part of the summer. Throughout 1910 fasciations in this species were few and far between in this same locality, though in other species, especially in *Linaria vulgaris*, they were frequent, though lacking, or at least so few as to escape observation, during 1909. In this particular lot I found but a single fasciation, in the latter part of the year, when, during the preceding week and more especially ten days earlier an exceptionally heavy rain had fallen.

The abnormality in the capitulum illustrated, perhaps analogous to that recently described for *Gossypium*,† is due to the foliaceous development of the outer row of scales of the involucre.** De Candolle†† described a similar abnormality in *Centaurea Jacea* which he recognized as the variety *phyllo-*

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*Contributons from the Botanical Laboratory of the University of Michigan, No. 122.

†Allard, H. A., An Abnormal Bract Modification in Cotton. Bot. Gaz. 49: 303. Fig. 1910.

**This abnormality is mentioned by Penzig, Pflanzen Teratologie, 2: 99 for both *T. officinale* and *T. palustre* and for the first species also by Masters, Vegetable Teratology, 243.

††Prod. 6. 51.

cephala, specimens of which later were found by Clos, [*] though in this instance the plant bore both normal and abnormal capitula. A similar abnormality has been described for *Centaurea lepidophylla.* [†] It is not infrequent in both *Plantago major* and *P. lanceolata* (*vars. polystachya*) and also has been reported for *Armeria plantaginea.* [**] In the appendix to his "De Antholysi Prodromus" Engelmann describes the same thing for *Hieracium*, *Pyrethrum* and *Coreopsis*. An answer to the question whether such a deviation could be inherited, involved the collection of seed and, since the plant was in an exposed position, its immediate transplantation to the experiment garden. Notwithstanding the care used in this operation the plant failed to re-establish itself and the flower had to be collected to make an alcohol specimen. It was a source of great satisfaction therefore, when, a week of so later, on another street, there was found growing upon a sloping bank, and in a position which precluded the probability of mechanical injury, another plant which showed two instances of the same abnormality. Mechanical injury might be supposed to have existed in the preceding instance. It is an important consideration, for there is undoubtedly a connection between mechanical injury and fasciation. I have noted during the last two years that the percentage of fasciated flowerstalks of *Taraxacum*, when growing along a street, appears to be greater in close proximity to the sidewalk than at some distance from it. In a single instance, when a large number of fasciations were found three feet from the sidewalk, *i. e.*, where I had been led to expect none or few, and on the contrary found a large number within a circle of a diameter of three feet, we were able to explain this apparent deviation from the rule by the fact that this particular spot was frequently trampled by the children of the neighborhood during their play.[††] In an earlier paper attention was called to the fact that fasciations may be accompanied by other abnormalities,* such as tubular flowers, something well illustrated by fig. 2 for which I am indebted to Mr. F. C. Gates. An apparently normal specimen of *Rudbeckia hirta* was collected in 1904 and transferred to a garden. The next year it still was normal, at least no peculiarities were noted. In 1906 the plant produced several fasciated stems, bearing inflorescences of which the flowers were more or less tubular. The plant continued to show fasciations up to 1909 when it died.

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[*] Clos, D., Recherches sur l'involucre des Synanthèrees Ann. Sc nat 3 Ser 16 40. 1851.

[†] Cassat, E., et J. Deysson Contribution a l'ètude des phènomènes de Tèratologie vègètale. Bull. Assoc. Franc Bot 3 80 1900.

[**] Bowles. *Armeria plantaginea* foliaceous. Gard Chron Ser 3 30 421 1901

[††] This may have been a mere coincidence for there are not lacking observations showing numerous fasciations in places which probably never were disturbed by man or animal and where other explanations, including inheritance are in order. It is hoped systematic experiments to settle this point may be undertaken in the near future.

Virescence often is noted in fasciated specimens.† Yet there are many instances on record where virescence existed without fasciation. Thus, some years ago, the cultivated asters seemed to suffer from virescence. In the same year we noted both virescence and frondescence in *Rudbeckia hirta* and in *Echinacea purpurea* without the slighest indication of fasciation. But on the roots of the different species an *Aphis* was found to exist. That the presence of an insect was the probable cause of virescence has been noted by others.** In some cases the doubling of flowers has been ascribed to insects infecting roots††. And while, without further proof, we cannot attribute the abnormality of the *Taraxacum* to this insect, at the

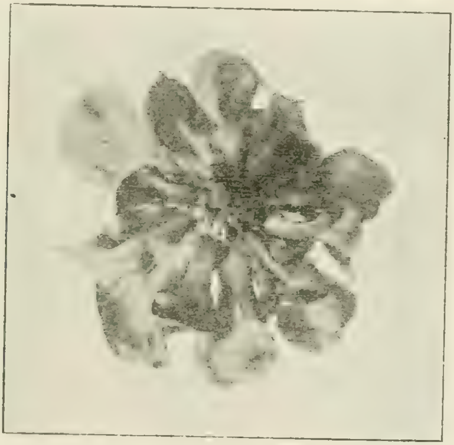

Fig. 1. Frondescent capitulum of *Taraxacum officinale.*

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*Hus, H. Fasciations of known causation. Am. Nat. 42: 81. 1908.

†De Vries found in a single locality specimens of *Crepis biennis* which showed fasciation, specimens showing torsion and virescent individuals. Over de erfelykheid der fasciatien. Bot. Jaarb. Dodonea 6: 72. 1894.

**Gerber, Ch., Fleurs virescentes de la Valeriana Chaussetrappe. Compt. rend. Soc. Biol. Paris 60: 57. 1906. (Due to *Trioza Centranthi.*)

††Molliard, M., Fleurs doubles et parasitisme. Compt. rend. 2: 548. 1902.

same time the fact that no such insect was found on the roots of the dandelions in question is not sufficient to ascribe frondescence of the bracts to possible mechanical injury, since in all probability this would have brought about fasciation. Plitzka[*] observed numerous instances of virescence in different Compositae and ascribed them to the effect of a fungus, *Puccinia compositarum*. He also noted that the abnormality was limited to those plants which grew on a soil rich in lime. Molliard[†] ascribes virescence of *Trifolium repens* to *Polynthrincium Trifolii* Kunze, while *Phytoptus* seems to have been

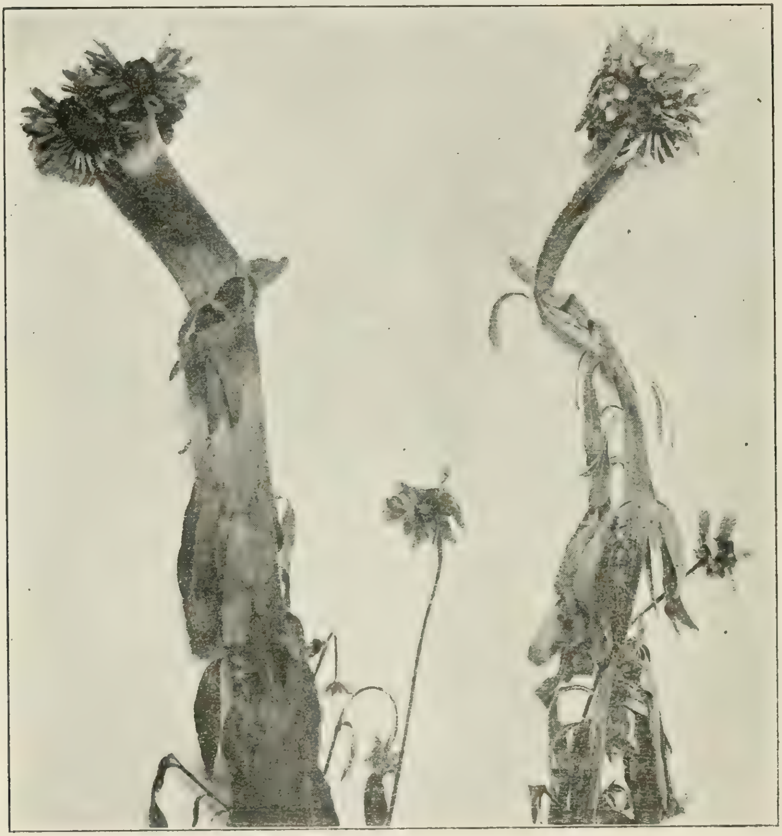

Fig 2 Fasciation of *Rudbeckia hirta* × 4/15

responsible for virescence of *Trifolium procumbens,*[*] and of *Trifolium arvense.*[†]

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[*] Plitzka, A., Beitrag zur Teratologie der Kompositen. Oester. Bot. Zeitschr. 52: 100, 159. 1902.

[†] Molliard, M., Cas de virescence et de fasciation d'origine parasitaire. Rev. gèn. de **Bot. 12**: 325. 1900.

The virescence of certain of the individual flowers of our *Taraxacum* evidently was not as pronounced as that of the plants mentioned by Pluskal,[**] for he calls especial attention to the infertility of the flowers. The Ann Arbor specimen however produced abundant seed, which was sown and yielded some eighty or ninety plants which up to the present have not flowered. From the results obtained we will be able to judge in a year or two whether this abnormal form is entitled to varietal rank. And while, *a priori*, we would not be inclined to take this view, it must be remembered that cases of virescence are known where not only the virescence reappears year after year,as in the strawberry [††],but that the virescence may be transmitted through the seed as in the case of *Oxalis stricta viridiflora.* In neither of these instances, certainly not in the last, the virescence appears to be of a pathological character. Other instances of virescence are known which could be ascribed to other organisms, plants or animals, as in the instances above quoted. Peyritsch[||] has shown that by transferring aphids from virescent to healthy plants, virescence may be induced. A third kind of virescence,of which the cause never was ascertained, has been known to assume the proportions of an epidemic which may last for years.[|||]

The second frondescent specimen of our *Taraxacum* enabled us to carry on experiments to determine the inheritance. It is rather expected that during the next year other such specimens will be found, for though the two described were the first we encountered, similar specimens have been noted before as shown by by the instances given above. A remarkably good specimen of this character appears to have been the one referred to recently *, and in which the abnormality was so great that, facetiously, the name *Taraxacum paradoxa* was suggested for the "new species."

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[*] Schlechtendahl, H. ,R. von., Uebersicht der Phytoptocecidien. Zeitschr. f. Naturw 55 1882.

[†] Nalepa, A., Neue Arten der Gattung *Phytoptus und Cecidophyes.* Densch. k. k Akad d. Wiss. 59 525. 1893.

[**] Pluskal, F S., Beiträge zur Teratologie und Pathologie der Vegetation. Oest Bot Wochenbl. 2. 371. 1852. Unfortunately I am unable to find Bruhin s "Neue Beiträge" which contains the original description of an abnormality similar to the one figured here and to which reference is made in his "Teratologische Beitrage," in Verh. k k. zool bot. Gesell. Wien. 17. 97. 1876.

[††] Holmes, Plymouth Strawberry. Gard. Chron. 3rd Ser. 30: 58. 1901.

[|] Hus, H., Virescence of *Oxalis stricta.* Ann. Rep. Missouri Bot. Garden. 18: 99. Pl. 10, 11. 1907. The distinction between virescence and frondescence shoule be kept in mind.

[||] Peyritsch, J., Zur Aetiologie der Cholranthein einiger Arabisarten. Jahrb. f. wiss. Bot. 13 .1 1882.

[|||] De Vries, H., Een epidemie van vergroeningen. Bot. Jaarb. Dod. 8: 66. 1896.

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STUDIES IN SOIL PHYSICS, V. †

SOIL TEMPERATURE.

E. E. FREE.

The close dependence of plant growth upon the existence of a proper surrounding temperature is a commonplace of plant physiology and as a part of the "surrounding temperature," the temperature of the soil is scarcely less important than that of the air. Furthermore, germination is even more closely controlled by temperature than is growth, and for germination the soil is the sole environment and its temperature the only one effective. Among the soil factors to which the physiologist and ecologist must give attention temperature is by no means the least. Nor is it legitimate to assume, as is often done, that the soil temperature is sufficiently indicated by the average temperature of the air. There is a relation, of course, but not a direct nor exclusive one. Soil temperature is not a static thing but results from a balance between the quantities of heat being added to the soil and being taken from it. When more heat is entering than is leaving the soil grows warmer; when the reverse condition obtains it grows cooler. Its temperature is seldom constant, being subject not only to the usual diurnal and annual cycles,but also to many accidental changes. The wider of these variations are climatic matters, under the the control of meteorological factors with which the specific nature of the soil has little or nothing to do. Such are outside our present interest. The soil character does, however, influence its temperature, and sufficiently importantly to have some physiological and ecological significance. This matter de-

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*American Botanist 15: 27. 1909.
†Published by permission of the Secretary of Agriculture.

serves a little nearer attention but as a preliminary thereto it will be well to review briefly the means by which heat is added to or abstracted from the soil.

The ultimate source of nearly all soil heat is the radiant energy of the sun, and indeed this is the source of much of it immediately as well as ultimately. Direct or reflected sunlight is the great soil warmer. The soil also loses heat by radiation, mainly during the night, but the amount is usually less than that gained similarly during the day. Next to radiation the largest additions or subtractions of heat are by means of the entering or leaving water. If the soil is cooler or warmer than the rain which falls on it this rain will warm or cool it and indeed this is frequently the most practical factor affecting the soil temperature. It may require days of sunshine to counteract the cooling effect of a few hours of cold rain. Of course the amount of heat ''added'' or ''subtracted'' by rain falling on the soil is measured not simply by the temperature of the rain but by the amount and sign of the difference in temperature between the water entering the soil and the same water as it leaves in the drainage. If the water leaves cooler than it entered it has warmed the soil, and conversely.

Besides radiation and added water there is only one major means of heat transfer -the loss of heat occasioned by the evaporation of water from the soil surface. Even this is only occasionally of practical importance and the previously named factors remain the only ones which need very careful consideration. There are also many still less significant ways in which heat is lost or gained, among which may be enumerated: (1) the heat derived from or given up to the air in contact with the soil, (2) the heat transferred by conduction to or from lower strata; (3) the heat derived from radioactive materials in the soil; and (4) the heat given up by plants[*] and animals to the soil. All these are very small in amount and entirely unimportant. From our present viewpoint it is also unnecessary to concern ourselves with the mechanism of the transfer of heat from place to place in the soil, especially as this matter has already been thoroughly discussed by Patten.[*] Essentially the heat equation of the soil is the balance of, (1), the heat added by radiation plus, (2), the heat added in rain water; against, (1), the heat lost by radiation plus, (2), the heat loss in the drainage water plus (in some cases), (3), the heat "absorbed" by evaporation from the soil surface.

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[*] Contrary to an opinion still sometimes expressed the soil does not give up heat to the plant. Quite the reverse. Under usual growing conditions the plant is nearly always warmer than the soil and heat flows from root to soil instead of in the reverse direction. The plant must be kept in warm soil not because heat, as such, is necessary to its growth but because it must be maintained at the temperature at which the enzymotic reactions upon which growth depends are able to go on. If the soil be too cold the plant looses heat so rapidly that this optimum temperature cannot be maintained.

This, however, is not the whole of the matter. We are interested not only in the temperature of the soil at any given moment but also in the rapidity with which this temperature will change under any given rates of heat supply and removal. For instance one of the most important questions in soil thermics is that of the rapidity with which various soils become warmed in the spring. These questions of rate of change are largely questions of specific heat.[†] The more heat required to warm a body the more slowly will its temperature rise under given heat supply. Now the solid constituents of the soil have all about the same specific heat, but the specific heat of water is about five times as great. Hence it takes much more heat to warm water than to warm dry soil, and much more heat to warm a wet soil than a dry one. Other things equal the wetter soil will warm more slowly and conversely, cool more slowly. This is a matter of no small practical importance and upon it depends the necessity of arranging that soils be well drained in the spring when their rapid warming is most desirable.

Turning now to the influence of the nature of the soil on these various thermal questions, we see, first, that the heat addded or subtracted as a result of warm or cold rains need receive no consideration. Such heat movements have nothing to do with the soil as such and are not sensibly affected by its nature, nor under the control of those who handle it. This leaves only the radiations,and of these,the positive radiation only is affected by the soil character. The amount of heat radiated from a soil depends only upon its temperature and not at all upon its individual properties. The amount of radiant energy absorbed is, however, considerably affected by one soil property—the color. In general darker colored bodies absorb and retain a larger proportion of the radiant energy which falls on them than do bodies of lighter hue, and soils behave like other substances in this respect. The darker the soil the more radiation it will absorb and, other things equal, the warmer it will become. However, the light colored soil by no means fails to absorb radiant energy altogether. It simply absorbs a little less and indeed, there is seldom sufficient color difference between ordinary soils to make any very great difference in the thermal absorption. Nevertheless color is of some importance, and it is the only soil property which materially affects the gains and losses of heat. From the practical viewpoint the variations in exposure (dependent upon topography, vegetal cover, etc.) have much more effect upon the supply of radiant energy, but these matters are so obvious and well known that their discussion here is hardly necessary.

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[*] Bull. 59, Bureau of Soils, U. S. Department of Agriculture.

[†] The specific heat of a substance is defined as the quantity of heat necessary to raise a given quantity of the substance through a given temperature interval. This same quantity of heat will be given up by the substance in cooling though this same interval.

The really important way in which the character of the soil influences its temperature is connected with the second question of rapidity of temperature change rather than with the gains and losses of heat. The amount of water which will be normally held by a soil depends upon its physical nature, * and it is obvious from the above that the more water retained by, and present in, the soil the higher will be the total specific heat of the system, and the more slowly will the soil be warmed. Thus a clay which holds thirty percent of water will warm much more slowly than a sand which holds only five percent. To this factor must be ascribed the well known tendency of sandy soils to warm early in the spring and their proverbial utility for the ''early'' vegetables.

So important is this matter of water content that it far outweighs color and any ordinary differences in exposure. Of two soils, one sandy, well drained and light in color; the other heavy and wet but very dark, the sandy soil will warm much the faster in spite of the apparent advantage given to the other by its darker color. Exactly this case is common in the truck regions along the Atlantic seaboard where the light colored sandy soils of the rises alternate with the much darker heavier soils of the slough bottoms. The light colored sandy soils are so much earlier that it would be quite impossible to convince a farmer of this region that dark colors assisted the warming of a soil.

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*As discussed in the second paper of this series Plant World 14, No. 3. (1911)

Bureau of Soils,
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Washington, D. C.

NOTES ON THE ROYAL MOCCASIN-FLOWER.

EUGENE E. BARKER.

The royal moccasin flower (*Cypripedium reginae* Walt. or *C. spectabile*, Salisbury and Swartz), as it grows in the foothills of the Adirondack Mountains, shows interesting and marked response to the intensity of sunlight it receives. This response to the amount of insolation is apparent in the size of the plant, the posture of the leaves, the abundance of bloom, and lastly, though probably indirectly, the number of flowers that set seed.

The more open parts of cedar swamps, where its fibrous roots feed in the cold, wet muck, are its favorite habitat. Here it attains to maximum luxuriance. When it grows in open sunlight, among only small cedars and stunted willows, the plants are stocky and the leaves point sharply upward, curving somewhat around the stem, and the flowers are pale in color for the most part. Those plants which grow in diffuse sunlight under the cedars are taller (about three feet high), the flowers have a richer hue, and the great expanded leaves spread horizontally to the light. There are however, fewer stems from each root,and a larger percentage bear no flowers than among those growing in the open.

When one cuts a stem close to the ground, he is surprised at the amount of water that runs from the cut end. This water was not in the stem, however, but held in the lowest leaf, which is small and clasping.

Rarely one finds a flower with the labellum pure white. Two such flowers were noticed this season growing together in the sunlight. The interior, as in normal flowers, was streaked. Two monstrosities were found, one with an anther on the face of the stigma, another that lacked the labellum.

There seems to have been little actual observation done upon the pollination of this flower. Darwin mentions bees as the implied fertilizers for the genus *Cypripedium*, and Gibson says ''doubtless many of the smaller bees do effect cross-fertilization in the smaller species.'' He says that he has often sat long and patiently in the haunt of the cypripedium, awaiting a natural demonstration of the cross-fertilization of *C. acaule*, but his devotion was never rewarded. He gives a charming description of the process however, as demonstrated for him by a captive bumble bee with cut flowers in his study. In *C. hirsutum* Dawin found that small bees were more servicable. Prof. Herman Müller studied *C. calceolus* for many years and gives the following description of its cross fertilization, which I quote in full,as it applies equally well to *C. reginae*, so far as my observations go. ''I have observed'', he says,

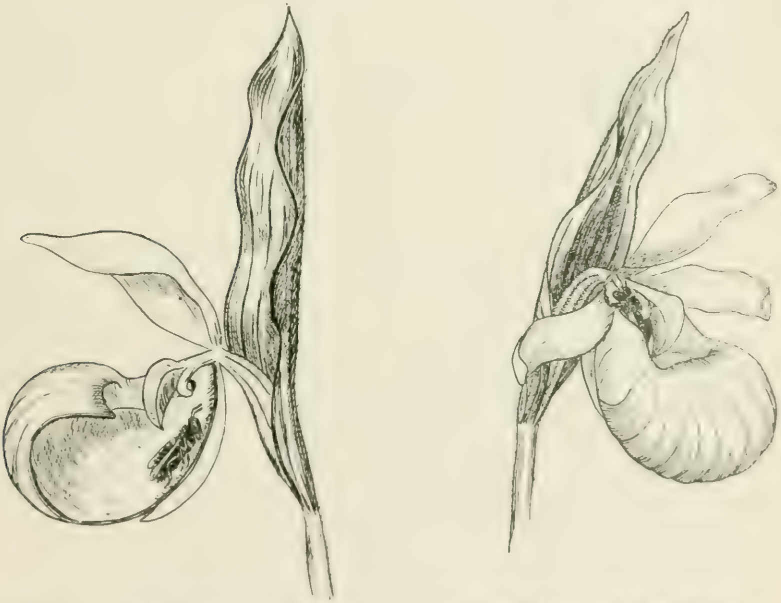

Fig 3. Sketches of the flower of *Cypripedium reginae*, showing manner of pollination

"five species of *Andrena* fertilizing the flower, viz. *A. nigroaenea* K, *A. fulvicus* K, *A. albicans* K, *A. striceps* K, (*A. tribialis* K.) and *A. pratensis* Nyl.. These bees attracted by the color and perfume of the flower, fly into the slipper-shaped lip, and bite the hairs lining its floor, which are sometimes covered with small drops of honey. They try for some time to escape by climbing up the vaulted sides of their prison towards the orifice that they entered by; at last, after creeping beneath the stigma, they manage with a great effort to escape by one of the two small lateral openings at the base of the lip; in doing so they smear one shoulder with a sticky pollen from the anther immediately above. In the next flower the bee, as it creeps up the stigma, leaves some pollen on its papillae, which are long and point obliquely forwards, then squeezing itself again through one of the small orifices it acquires another load of pollen: cross-fertilization is thus effected regularly."

Last summer I spent several hours in the habitat of the royal moccasin flower watching the plants and their insect guests. The only insects seen to visit the flowers were bees,and they effected cross-fertilization for this species in exactly the manner described by Müller for *C. calceolus.* The bees were captured in the act, and later identified as all belonging to the genus *Andrena.*

What good they obtained when visiting the flowers I have not discovered. So far as I can detect, no nectar is secreted, either inside the labellum, or within its tissues. Possibly the hairs fringing the lining are eaten as Müller observed. Darwin speaking of the genus in general says, "I have never been able to detect nectar in the labellum," and Kurr makes the same remark with respect to *C. calceolus.*

Last year's stems persist bearing the seed pods, and attest an intimate relation between plant and insect. The great number of seedling plants to be seen gives further evidence. In order to get a more definite idea of the exact proportion of flowers that are pollinated I made a careful count of blossoms and last year's seed capsules. As the amount of bloom on each plant is very constant from year to year,the comparison of the seed of last year with the bloom of this year seems valid. The following tables give the data obtained.

TABLE I—PLANTS GROWING IN THE OPEN.

No. of stems to a plant	Total bloom on a plant	No. of stems bearing two flowers	No. of stems with single flower	No. of stems with three flowers	No. of stems with no flowers	No. of last year's seed pods
7	10	4	2	0	1	8
9	12	5	2	0	2	6
12	12	5	2	0	2	6
11	18	8	2	0	2	7
11	21	8	2	1	0	9
15	28	11	3	1	0	23
6	10	4	2	0	0	7
15	28	10	2	2	1	25
22	32	12	8	0	2	13
17	29	10	6	1	0	12
6	8	2	4	0	0	1
4	7	3	1	0	0	3
19	34	15	4	0	0	38
16	23	9	5	0	2	11
2	4	2	0	0	0	1
7	13	6	1	0	0	1
13	16	4	8	0	1	6
7	8	3	2	0	2	6
4	1	1	3	0	0	3
203	326	124	60	6	13	191

TABLE II—PLANTS GROWING UNDER CEDARS IN SHADE.

No. of stems to a plant	Total bloom on a plant	No. of stems bearing two flowers	No. of stems with a single flower	No. of stems with no flowers	No .of last year's seed pods
13	18	8	2	3	3
1	2	1	0	0	0
3	1	0	1	2	0
6	7	2	3	1	2
3	4	1	2	0	0
3	6	3	0	0	2
5	9	4	1	0	1
11	2	0	2	9	2
8	4	0	2	5	0
1	2	1	0	0	0
2	2	1	0	1	1
3	2	1	0	2	2
59	59	23	13	23	13

TABLE III—COMPARING PLANTS IN OPEN AND SHADE.

	In open	In shade
Total number of plants counted	19.	12.
Total number of stems counted	203	59
Total number of flowers counted	326	59
*Average number of stems to a plant	10.68	4.91
Per cent of stems bearing no bloom	6.01	39
Per cent of stems bearing bloom	93.99	61
Per cent of stems bearing two flowers	61.	39
Per cent of stems bearing one flower	21.56	22
Per cent of stems bearing three flowers	2.95	00
Per cent of last year's pods to this year's flowers	58.58	22

*Not a fair conclusion for the whole population, because many single stems and smaller groups in the open were not counted.

Table III brings out quite strikingly the differences of growth due to amount and intensity of sunlight to which the plant is exposed. Those growing in shaded situations (although the flowers are more deeply colored) bear hardly more than half as many flowers as those growing in the open, the percentage of barren stalks is over six times as great, and the profusion of flowers to a single stem is markedly less. No measurements were taken as to height, but my opinion is, that the shaded plants would average several inches taller.

Bees of the genus *Andrena* were found to be the customary agents for effecting fertilization in this species, As they work during the warm sunny hours, and would naturally frequent most the more conspicuous and accessible flowers growing in the open glades, the fact that over half the flowers in the open set seed, while only a little more than one-fifth of those among the cedars do so, would seem significant as evidence that *Andrena* is the pollinating agent for this plant.

Cornell University,
Ithaca, New York.

BOOKS AND CURRENT LITERATURE.

THE PHYSICS OF TRANSPIRATION.—Students of plant transpiration in its pyhsical aspect will be interested in the recent studies of Renner * upon the influence of the size, shape and position of an evaporating surface upon its rate of water loss. This paper is a continuation of the author's earlier studies† upon the relation of form, position, etc., of foliage leaves to their transpiration rates, with especial reference to the vapor blanket which tends to cover foliar surfaces in quiet air. In the recent contribution, Renner is occupied with physical evaporation from water surfaces and from the surface of wet blotting paper. Pieces of the latter material were supported on glass plates and care was taken that neither too much nor too little water was added, to produce complete saturation. After wetting the rate of evaporation remained constant (under constant conditions) for an hour or longer, during which time the experiments were carried out. The rate of water loss per unit area was, in this first hour, not markedly less than that from a free water surface.

The following points are brought out:- Paper circles and circular pans of water, placed upon a balance, lost about ten percent more water when the balance was slowly and just perceptibly swinging than when at rest. If the rate of evaporation from horizontal paper surfaces be increased by wind to six times its original magnitude, the original rate is regained in not over two minutes after the wind ceases. Two parallel vertical paper surfaces fail to influence each other sensibly when but two cm. apart. When nine mm apart their rate of water loss is decreased only twenty-five percent. The water vapor thus diffuses but little laterally from such surfaces. Circular and rectangular papers lose moisture more rapidly when vertically than when horizontally placed. Water loss is more nearly proportional to the linear dimensions of the surfaces than to their areas, though various conditions modify the proportionality. Of two rectangular surfaces with equal areas but with different forms (in still air), the narrower always loses considerably more water per unit of time than does the broader. This is of great fundamental importance in comparisons

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*Renner, O., Zur Physik der Transpiration. Ber. d. d. Bot. Ges. 29: 121-35. 2. 1911.

†Renner, O., Beitrage zur Physik der Transpiration. Flora, 100: 485. 1910.

between the rates of transpiration from differently shaped leaves; it is to be related to the effect of the vapor blanket, the margins of a surface being much more efficient in evaporation than the central portion.

It is clear from Renner's admirable analytical studies that the underlying physical principles of plant transpiration (even when all intra-foliar changes such as stomatal movements etc., are corrected for) are not simply those of gas diffusion. The phenomena are modified by size, shape and position of the leaves, so that, as the author well points out, it is essential to understand these physical modifications as far as possible, so as to avoid confusion of these with supposed physiological regulation.—BURTON E. LIVINGSTON.

MENDELISM.—Punnett has published a new edition of this excellently written treatise on Mendelism,* which brings it up to date and makes it, like the two preceding editions, the most readible account of recent progress in working out the laws of heredity. No attempt is made at exhaustiveness but each phase of the subject is illustrated by typical cases chosen mostly from the experiments of Bateson and the author's other associates at Cambridge, England. The checker board method of solving Mendelian problems is presented with great simplicity and used with such frequency that the reader will gain a clear conception of the method and its usefulness. In one of these checkerboards (p. 52) three squares are blackened which should be white, and three squares which contain C and B and which should therefore be black are labeled "albino." The author omits all discussion of the chromosomes on the ground that there is not sufficient unanimity of opinion as to their significance in relation to Mendelism to make a discussion of them suitable for popular treatment. The reviewer considers this omission unfortunate, and believes that a chapter on the chromosomes presented with the same clarity that characterizes the other chapters, would have added value to the book. The introduction of many excellent figures and six plates, five of which are colored, lend attractiveness to this new edition and will materially aid the reader in comprehending the nature of the problem and the method of its solution. General readers, teachers and those primarily interested in other fields of science, but who desire to keep in touch with the work being done in genetics, will find Punnett's book a delightful source of information.—GEO. H. SHULL.

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*Punnett, R. C., Mendelism. Third edition entirely rewritten and enlarged; pp. 14 192. Figs. 32. Pls. 6 and frontispiece portrait. 1911. New York: Macmillan Co. $1.25

DRY FARMING.—Briggs and Belz have made a study[*] of the rainfall and evaporation conditions which prevail in the semi arid portions of the United States in their relation to the practise of dry farming. The region in which this form of agricultural endeavor has been developed is the northern part of the Great Basin and the western edge of the plains, where the annual rainfall is less than 20 in and more than 10 in. The authors call attention to the importance of the seasonal distribution of the rainfall, to the deceptive appearance of annual totals of rainfall in regions of torrential rains, and to the vital importance of evaporation in offsetting the apparent value of a given amount of rain.

In southern Washington dry farming is being successfully conducted in a region with winter rainfall of 10 in. and less, by the method of alternate cropping the summer fallowing. In Utah 13 in of rain is the minimum fall that permits of dry farming methods. In North and South Dakota low yields of wheat are obtained on from 5 to 8 in. of rain, which falls chiefly between April and July. Near San Antonio, Texas, the growing of sorghum has been possible with an annual fall of 13 in., a seasonal fall of 8 in., and a doubling of this fall in other years has given seven times as great a yield.

The total evaporation from April to September, as measured in the tanks of the dry farming stations of the Bureau of Plant Industry, are from 50 to 60 in. for Nevada, southern Arizona, the panhandle of Texas and southern Kansas, and from 30 to 38 in. for the Dakotas.—F. S.

NOTES AND COMMENT.

A recent bulletin of Washington University, in cooperation with the Missouri Botanical Garden, announces twenty five courses in botany and opportunity for research in Taxonomy, Applied Mycology, and Physiology, as well as independent research open to persons qualified to carry it on. The extensive equipment, consisting in part of a new and well equipped fireproof laboratory, a library of over 60,000 books and pamphlets, an herbarium of over 600,000 sheets of specimens, and a collection of living plants including upwards of 10,000 species or varieties, may be taken as some indication of the facilities now offered to botanical students and investigators. From this institution, whose complete equipment for such work is comparatively recent, if we pass in review such of the older universities as Harvard, Columbia, Cornell, Pennsylvania, Michigan, Chicago, and as many more state and other institutions, we can not fail to observe in this country a development of facilities for instruction, and especially for research, in various departments of botany that is hardly short of phenomenal. The explanation appears to be that the subject which within the memory of many of us was treated with kindly indulgence, or in some cases with supercilious contempt, by members of the philosophical faculty has proven its educational value, which is now freely admitted on every hand, and furthermore that its practical applications have become so numerous and important that they are frankly recognized and liberally provided for as matters of state and nation-wide concern. There is perhaps no subject in the school curriculum the status of which has so completely changed within a relatively short period of time.—V.M.S.

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[*] Briggs, L. J. and Belz, J. O. Dry Farming in Relation to Rainfall and Evaporation. Bur. Pl. Ind. Bull. 188.

The Catalogue of the Agricultural Exhibition of Switzerland held at Lausanne in 1910, contains various suggestive contributions, among which is a noteworthy one on the plants of Switzerland that serve as soil indicators, by Dr. C. Schröter. The author divides the plants under consideration into three classes: 1. Such as are strictly confined to a particular quality of soil, *e. g.* humus plants. 2. Those that show a preference for certain soils without being strictly confined to them. 3. Plants so far indifferent to the substratum that they cannot be employed as indicators of soil factors

Certain principles stated at the outset show that the study involves constant allowance for and widespread knowledge of the concurrent action of various factors. These include (1)

The behavior of other species. Many halophytes thrive in cultivation on soils that are salt. They do not require the salt; they merely endure it better than other species,occuring in nature in salt spots, on or the sea shoree, etc., where the latter cannot compete with them. (2) Influence of other soil factors. The soil presents a trying composite of physical, chemical and organic factors which may mutually influence and replace each other, so that the dependence of plants on one of them is often influenced by the action of others. Many plants that shun limestone, for example, will endure large quantities of lime in the soil if they are provided with a sufficient supply of potash. (3) Influence of climate. Climatic factors may to a degree replace soil factors; in a moist climate the same plants may thrive on a dry soil which would avoid this in a dry climate

With optimum climatic conditions a species is often indifferent to soil in the center of its range, while at the periphery of its area of distribution, where it is less capable of resisting unfavorable climatic conditions, it becomes established only on soils best suited to it, and it becomes there a soil indicator. (4) Physiological varieties. There is no doubt that certain kinds of soil influence many plants in such a way that "soil varieties" arise which in cultivation on other soils may return to their normal form. Examples of these are the well-know forms of fern on serpentine and of violet on zinc soils. Such "soil varieties" occur in nature only on the soils to which they belong.

Physiological varieties, not distinguishable by external characters, may arise on granite or limestone for instance which deport themselves quite differently under different external conditions. In regions where other conditions are better suited to the "limestone form" this may become dominant and appear to be an indicator of limestone, in others the "granite form" thrives best, and in a third region both thrive and the plants appear as if indifferent to the kind of soil.

Plants as soil indicators are considered in their relations to chemical constituents of the soil, humus content,and moisture. Only the first and second are discussed, the former at length and with special reference to plants belonging to limestone and other rocks as studied by the author in Switzerland. The painstaking collection of data and the theoretical considerations and conclusions are too voluminous for reproduction but should be duly weighed by students of plant distribution.—V.M.S.

The choice of crops for alkaline land is discussed by Thomas H. Kearney in Farmer's Bulletin 446 of the United States Department of Agriculture. To get rid of the excess of salts in alkali soils by flooding and drainage is expensive, and often impracticable, hence it becomes necessary to investigate carefully the relations and possible adaptations of various crop plants to such soils. Thus a question primarily economic becomes one of great scientific interest and in spite of its difficulties good progress is being made towards its solution. The author's statement of principles suggests at once the complicated nature of the problem. In the first place it is shown that the mere statement of the percentage of alkali in a soil tells us little about how plants will be affected. Some plants which can endure one percent of alkali if present in a heavy soil, would quickly perish in a sandy soil containing the same quantity and the same kind of salts, the reason being that the heavier soil can hold more water. Again in regions of winter rainfall like California a winter crop might succeed better in alkali land of a given concentration that a summer crop that is actually more resistant. The vertical position of a given quantity of alkali in the soil in relaiton to the depth reached by plant roots is also an important matter. Thus, for example, a comparatively small quantity of alkali near the surface will prevent crops starting that might grow well if a heavy rain or irrigation has occurred just before planting, resulting in driving much of the alkali into lower depths of the soil. Crop plants adapted to different grades of alkali in soils are discussed at length and useful practical suggestions are given which give the impression of careful scientific weighing of the complicated interrelations of the factors involved.—V.M.S.

William Russell Dudley, Professor of Systematic Botany in the Leland Stanford Junior University from 1892 till 1911, died on June 4, 1911, at the age of sixty-two. By ancestry and place of birth a New Englander, a graduate and for twenty years a member of the botanical staff of Cornell University, a student of De Bary's for a time in Strassburg,he brought to California the mature powers of an enthusiastic student and sympathetic lover of nature, the ripe scholarship and the winning personality of the inspiring teacher. At home in the laboratory,he was still more strikingly the gracious host when he was with students and other friends out of doors, in the fields and woods and mountain forests.

He knew the forests of middle California as no one else; his acquaintance was with individual trees, as his collection of tree portraits testifies. And his studies of their geographical distribution, following and amplifying the earlier studies of Asa Gray and others, gave his knowledge a degree of accuracy and detail, as well as breadth, which was very precious. It is to be hoped that his notes and other manuscripts are in such condition that his associates and successor can give them to the world.

Professor Dudley's nature was so sensitive, his perceptions so fine, and his ideals so high, that he could but rarely bring himself to publish what he knew. He wished always to add to and improve what he had learned and written. Thus the botanical world had little opportunity to know his accomplishments and achievements.

Besides the young men and women whose lives he has enriched, and the Forest Service which he long assisted in various ways, he contributed to the great gift to California and the Nation which the State and National Forests of California constitute. The "Big Basin Park," the property of the state, will preserve to all time a part of the natural redwood forest of the Santa Cruz Mountains. Professor Dudley assisted in securing and preserving as a state park this part of the virgin forest of *Sequoia sempervirens*. It was his interest too which stimulated and directed the federal authorities in the selection of others of the mountain forests of California as national forests.

Of courtly manner, cultivated as well as educated, of ripe scholarship and rich in the knowledge of nature, he was a loveable and elevating associate, an inspiring teacher, a devoted man of science, an honor to Stanford University of which he was an honored member.—G. J. P.

Mr. George B. Rigg, of the University of Washington, has devised a useful method for preparing large algae such as *Nereocystis*, *Laminaria* and *Alaria* for demonstration purposes, regarding which he writes as follows: "If specimens of any of the larger algae are taken from the water and dried at once in the sun they will keep, but they are too brittle to be handled without breaking. Specimens, may of course, be preserved in liquid preservatives but they are not convenient for handling on account of the liquid dripping from them. If preserved in formalin they tend to become soft after a few months The writer has used the method of soaking these algae in the following solution: tap water, 84 percent; glycerine, 15 percent, formalin, 1 percent. The plants were taken directly from the water and placed in the solution in a wash tub, where they were left for 48 hours and then spread out in the sun to dry. About two dozen specimens of *Nereocystis leutkeana* were first prepared. Later a few specimens of *Alaria valida*, *Laminaria saccharina*, and *Rhodymenia pertusa* were prepared. The first plants prepared have been used during the past year for demonstration purposes and for gross study in the laboratory in the elementary botany course in the University of Washington. They have all been kept in a wooden box without cover. At the present time (May 1911) they are in satisfactory condition, being flexible enough to be handled without breaking. It is observed that those kept in the top of the box show a slight tendency to become brittle, but the flexibility of those kept deeper in the box is entirely satisfactory. None of the sporophylls of *Alaria* have broken off, and there has been no collapsing of the bulb or of the hollow part of the stem in the *Nereocystis* specimens. All of the plants are slightly oily to the touch but not enough so to be very objectionable, and are of the consistency of very thin leather, No attempt was made to procure the largest specimens available, the plants selected being of ordinary size. The largest specimen of *Nereocystis* prepared measures 27 feet from the holdfast to the bulb, and the fronds measure 10 feet, making a total length of 37 feet. The largest specimen of *Alaria* prepared is 10 feet in length, and the largest one of *Laminaria* is 3 feet. The only difficulty met with in treating these plants was that of removing them from the solution and spreading them out without tearing the fronds. This difficulty was especially great in the case of *Nereocystis* because the numerous narrow fronds tangled badly, When, however, they were once spread out in the sun, they became tough in a day or two."

In September 1910 I came upon a young sycamore tree with unusually large leaves, the largest of which measured 16, 18 and a little over 21 inches across. The tree, which had a height of only seven or eight feet, was situated in a very shady place on the banks of the Little White Oak Bayou at Houston, Texas. It grew under a full grown sycamore, which came in contact with a dense growth of tall weeds on the steep slope above and interlocked with the branches of trees on the other side of the bayou. By this practically all the sunlight was excluded. The young tree was very slender, scarcely more than an inch thick at the base, and bore no lateral branches, its whole energy being apparently spent in the manufacture of leaves The size of the leaves of *Platanus occidentalis* L., the sycamore of this region, is given by various writers as from 4 to 9 inches in diameter. These leaves were, therefore, far in excess of the maximum recorded size.—R. A. STUDHALTER.

The manner is well known by which the pollen masses of the Asclepiads are extracted and carried off by insects whose limbs are caught by the gland which unites these twin masses. It does not seem to have been noted, however, that this apparatus may also sometimes act as an insect trap. Such is the case with the large flowers of *Asclepias eriocarpa*, a species common on the plains of southern California. Not infrequently honey bees, alighting on the umbels of this species, have several of their legs seized by the sensitive glands of different pollen masses, which they are then unable to extract, and so are held until they die. As many as six or seven dead or dying bees may be found on a single umbel. -S. B. PARISH.

The reference in the June number of THE PLANT WORLD to the work of Mr. S. B. Parish on "The Southern California Juncaceae" was, unfortunately, worded so as to leave the closing lines quite ambiguous. The writer of the notice requests us to make plain that Mr. Parish is *not* the man who published in Muhlenbergia a species distinguished as follows: "The perianths are larger in the species here proposed as new; but a better character * * * is the great length of the oblong and leaf-like segments of the involucre."

Volume 14 Number 9

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

SEPTEMBER, 1911

A STUDY OF THE RELATION BETWEEN SUMMER EVAPORATION INTENSITY AND CENTERS OF PLANT DISTRIBUTION IN THE UNITED STATES

BURTON EDWARD LIVINGSTON

Since by far the major portion of the water absorbed by ordinary green plants merely passes through the plant body and is lost in transpiration, it naturally follows that the transpiration rate is itself the main condition which determines what may be an adequate rate of water supply to such organisms. But, as was first quantitatively shown in Publication 50 of the Carnegie Institution (1906), the main condition which determines the intensity of transpiration from any plant is the evaporating power of the air, and when an instrument became available by means of which it is possible rather readily to measure and integrate this complicated climatic factor somewhat as it affects plant transpiration, it was suggested that comparative determinations of the various intensities of the evaporating power of the air which prevail in the different parts of the United States in summer should furnish us with an approximate measure of the demands of transpiration water which the surrounding air makes during the season of greater plant activity, upon the vegation of the different regions. In other terms, it appears that the intensity of evaporation during the growing season should offer a climatic criterion from which might be derived a somewhat satisfactory correlation with the general facts of plant distribution. This seems the more promising when considered with the fact that the same general meteorological conditions which promote evaporation tend to render the precipitation low The publication of Transeau's pioneer study [*] of the relation between vegetation and the precipitation-evaporation ratios for the eastern part of North America gave added interest to this problem, for the charts of this author seem clearly to indicate a very definate correspondence between the nature of any vegetation type and the ratio of annual rainfall to annual evaporation for the region occupied by that type.

In so far as climatological features control the present distribution of the vegetation of the world, it is to be expected that the quantitative relations existing between these features and the vegetational characters will prove to be rather a complex one,and it will no doubt require long continued study to enable us definitely to express these relations. The integrations of many meteorological elements, for various portions of the year, will need to be considered, in the synthesis of the much-desired climatological formula for plant distribution. Since Transeau's (1905) and the writer's (1906) studies on the relation of plant occurrence and behaviour to evaporation intensity seemed to attribute an importance to this particular factor which had never before been emphasized, it seemed desirable that the general relations between the evaporating power of the air and the nature of the vegetational cover be explored from several different standpoints. It must thus be understood that the present study aims, not at all to displace the method of annual ratios, which was the first recorded attempt to interpret plant distribution quantitatively in terms of a climatic function involving evaporation, but rather to test one other method for studying the relationship concerned. It was of course to be expected that the two methods, of annual ratios and of summer evaporation intensity, would not exhibit a detailed agreement; the very nature of the problem and of the data involved precludes such agreement, and it is only along broad, general lines that the results of such studies may at the present time be scrutinized.

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[*] Transeau, E. N., Forests of Eastern America. Amer. Nat. 39: 875-98. 1905. Idem, Climatic centers and centers of plant distribution. Mich. Acad. of Sci., 7th Ann. Report, 1905.

The only series of observations on the intensity of evaporation in the United States,* which has been heretofore available, and that used by Transeau, is that made by T. Russell † for the period July, 1887, to June, 1888, inclusive. These are not direct observations, but deductions from readings of the wet and dry bulb thermometers and the barometer, and are of uncertain accuracy on account of the incompleteness of the formula by which they were computed. It was therefore deemed worth while to attempt a series of direct evaporation observations over the United States throughout the summer months and to compare the results with the general vegetational characters of the various parts of the country. The measure used was the rate of water loss from the porous cup atmometer, which is affected by external conditions in much the same manner as are ordinary plants, and which automatically sums the records, so that readings may be taken at any suitable intervals of time. This work was carried out** under the auspices of the Department of Botanical Research of the Carnegie Institution.

The plan was first put into operation in the spring of 1907. Porous cups were sent to twenty-four stations, fairly well distributed over the United States, and were operated, with weekly readings, for a period extending from May to September. The cups were placed in the open, with free access of sunshine and of wind. The center of the cup was fifteen centimeters above the soil surface, so that the records may be considered as approximately proportional to the evaporating power of the air as this would affect the transpiration of a plant of about the above named height, growing in the open.†† The details of the installation of the instrument have been presented in a paper on "Evaporation and Plant Development," (Plant World 10: 269-276. 1907), and need not here be repeated. At the end of the season the porous cups were returned to Tucson and there standardized, the readings obtained by the observers being afterward corrected according to the coefficients thus obtained.

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*Perhaps the best series of observations on the intensity of evaporation which has so far been recorded is that of T. Okada, Evaporation in Japan. Bul. Cent. Met. Obs., Japan, 1904, No. 1, [illegible]. A general review of the literature of evaporation of throughout the world has been published by Grace J. Livingston, An Annotated Bibliography of Evaporation, Monthly Weather Review for June, Sept., and Nov., 1908, and Feb., March, April, May and June, 1909. The student of this subject will find many suggestions and much of general interest in the recent publication by Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. Bulletin 188, Bur. Plant Ind. U. S. Dept. Agric. pp. 71. 1911.

†Russell, T. Depth of evaporation in the United States. Mo. Weather Rev., 16: [illegible] 1888.

**The instrument was first devised in its essentials by Babinet. Compt. rend. 27: 529-530. 1848. It was later independently devised by A. Mitscherlich. Landw. Versuchsstat. 60: [illegible], and 61: [illegible] 1904; and by the writer (Publ. 50, Carnegie Institution. 1906). The literature of this form of atmometer is presented in Plant World 13: 111. 1910. On a modification of the instrument, see Transeau, E. N., A Simple Vaporimeter, Bot. Gaz. 49: [illegible] 1910.

††As has been later pointed out (Bot. Gaz. 1911) evaporation from the white clay cup is not influenced so much by sunshine as is transpiration from green leaves. Thus the results here reported do not adequately include the influence exerted by sunshine. But, since the regions of highest evaporation intensity are usually those of greatest solar illumination, our records may probably be considered as showing at least the correct order of magnitudes, even if the influence of sunshine be included.

The results of this series of observations have been published in the author's article upon "Evaporation and Centers of Plant Distribution," (*Plant World*, 11: 106-112. 1908), on page 110 of which will be found a table showing the "Relative evaporating power of the air at 16 stations in the United States, June 3 to Sept. 30, 1907," together with the names of the observers who so kindly co-operated, and thus made this work possible by attending to the instruments.

These results were unsatisfactory and inadequate to our purpose, one reason for this being the smallness of the number of stations, so that anything like an evaporation chart of the country could not be attempted therefrom. An attempt was, however, made (in the last article cited), to draw tentative comparisons between the intensities of evaporation for the regions occupied by three of the vegetation centers, and the corresponding rain-evaporation ratios for the entire year as these were derived by Transeau (1905). Since typographical errors rendered the conclusions from this comparison obscure, they may be repeated here. We may take, from Transeau's map, the annual rain-evaporation ratios: 1.25, 1.05, and 0.20 as representing approximately the regions occupied by the northeastern conifer center, the deciduous forest center, and the southwestern desert center, respectively. Considering the first ratio as unity, this series of ratios becomes 1.00, 0.84, 0.16. From our own data we derive the generalization that the different evaporating powers of the air for the summer of 1907, for these three centers should be about 1.00, 1.16, and 2.86, respectively. The reciprocals of these numbers give us 1.00, 0.86, 0.35, to compare directly with 1.00, 0.84, 0.16, from Transeau. The agreement between 0.86 and 0.84 is surprisingly good. The discrepancy between 0.35 and 0.16 means little when taken with the data for the following year which are to be given below.

The data derived in 1907 were so satisfactory, and at the same time so incomplete, that it was decided to continue the operations through another season. Steps were accordingly taken, with very helpful suggestions from Dr. E. N. Transeau, now of the Eastern Illinois Normal School, and with Dr. Forrest Shreve, now of the Desert Laboratory, to increase the number of stations and otherwise improve the character of the results. The writer's absence from the United States during the year 1908 would have made it impossible to secure a series of observations for that summer, had it not been for the hearty and efficient co-operation of Dr. Shreve, to whose enthusiasm and perseverance the 1908 results are entirely due. Dr. Shreve took complete charge of the operations throughout the season.

In this series, the results of which it is the purpose of the present paper to report, two standardized porous cups were sent to each observer at the beginning of the season. These were installed side by side, each placed as in 1907, and weekly readings were made on both until mid-summer, when *one* of the cups was returned to the Desert Laboratory and restandardized by Dr. Shreve. This restandardized cup was then returned to the observer, by whom it was again installed in its old position, and operated with its mate till the end of the season. By this method determination was made possible of the amount of variation occurring in the correction coefficients of the various cups, without at the same time interrupting the series of observations. At the end of the season both cups were returned to the Desert Laboratory and all were standardized by the writer during the spring of 1909. All standardizations in this series were made with reference to standard cups, the standard being directly or indirectly derived from the original standard of the fall of 1907. It is this same standard to which all coefficients derived since that time have been made to refer. It will be remembered that the reading of any cup is to be multiplied by its coefficient of correction, to give the reading which the standard cup should have given for the same time and place.

Where the coefficient of correction of any cup altered, as shown by the mid-summer and final calibrations, interpolations

TABLE I.

MEAN WEEKLY EVAPORATION RATES, AS RECORDED BY THE POROUS CUP ATMOMETER, FOR 38 STATIONS, DURING THE PERIOD OF 15 WEEKS FROM MAY 25 TO SEPT. 1, 1908.

Station and Co-operator.	May 25 to June 29.			June 29 to Aug. 3.			Aug. 3, to Sept. 1			Average.		
	cc.	cm.	in.	cc.	cm.	in.	cc.	cm.	in.	cc.	cm.	in.
Seattle, Wash.												
Prof. T. C. Frye,	....	....	....	167	2.36	0.93	96	1.36	0.54	132[2]	1.87	0.7[4]
Eugene, Ore.,												
Prof. A. R. Sweetser	95	1.35	0.53	210	3.10	1.22	179	2.53	1.00	164	2.32	0.91
San Diego, Cal.,												
Hon. A. Campbell	221	3.13	1.23	201	2.85	1.12	203	2.87	1.13	208	2.95	1.16
Regina, Sask,												
Mr. T. N. Willing.	181[4]	2.56	1.01	118	1.67	0.66	70	0.99	0.39	156	2.21	0.87
Bozeman, Mont.,												
Prof. D. B. Swingle.	39	0.55	0.22	162	2.29	0.90	150	2.12	0.84	117	1.66	0.65
Reno, Nev.,												
Prof. J. E. Church, Jr.	....	....	....	487[4]	6.90	2.72	387[3]	5.48	2.16	437[2]	6.19	2.44
Salt Lake City,												
Prof. O. E. Garrett.	72	1.02	0.40	170	2.41	0.95	178	2.52	0.99	140	1.98	0.78
Tucson, Ariz.,												
Dr. W. B. McCallum .	511	7.24	2.85	350	5.07	2.00	249	3.53	1.39	373	5.28	2.08

TABLE I.—Continued.

Station and Co-operator.	May25 to June 29			June 29 to August 3.			Aug. 3 to Sept. 1.			Average.		
	cc.	cm.	in.	cc.	cm.	in.	cc	cm.	in.	cc.	cm.	in.
Boulder, Colo., Prof. F. Ramaley.	180	2.55	1.00	161	2.28	0.90	216	3.06	1.20	186	2.63	1.59
Dalhart, Texas, Mr. F. E Kennard.	565	8.00	3.15	404[4]	5.72	2.25	440	6.23	2.45	470	6.66	2.62
Dickinson, N. D., Mr. E. R. Waldron.	268	3.79	1.49	315	4.46	1.76	258[4]	3.65	1.44	280	3.96	1.56
North Platte, Neb. Mr. W. W. Burr.	138	1.95	0.77	127	1.80	0.71	171	2.42	0.95	145	2.05	1.81
Winnipeg, Prof. A. H. R. Buller.	....	....	....	156	2.21	0.87	....	....	....	....	....	....
Lincoln, Neb., Mr. G. A. Loveland.	73	1.03	0.41	....	....	....	134[4]	1.90	0.75	103[2]	1.45	0.57
Stillwater, Okla., Mr. J. F. Nicholson.	109	1.54	0.61	191	2.70	1.06	163	2.31	0.91	154	2.18	0.86
Minneapolis, Minn., Prof. F. E. Clements.	....	....	....	144	2.04	0.80	159	2.25	0.89	151[2]	2.14	0.84
Iowa City, Prof. R. B. Wylie.	....	....	....	....	....	....	139	1.97	0.77	....	....	....
St Louis, Mo., Prof. H. Hus.	152	2.15	0.85	154	2.18	0.86	176	2.49	0.98	161	2.28	0.90
Cameron, La., Mr. C. H. Anderson.	234	3.31	1.30	167[3]	2.36	0.93	116[4]	1.64	0.65	172	2.44	0.96

Station and Co-operator.	May 25 to June 29			June 29 to Aug. 3.			Aug. 3 to Sept. 1.			Average.		
	cc.	cm.	in.	cc.	cm.	in.	cc.	cm.	in.	cc.	cm.	in.
Houghton, Mich., Mr. James Fisher.	....	....	....	127	1.80	0.71	163	2.31	0.91	145^2	2.05	0.81
Ubana, Ill., Prof. H. A. Gleason.	113^4	1.60	0.63	110	1.56	0.61	....	....	....	112^2	1.59	0.62
Charleston, Ill Prof. E. N. Transeau.	189	2.68	1.05	158	2.24	0.88	....	....	....	174^2	2.46	0.97
St. Helen, Mich., Mr. John Carter.	....	....	....	201^2	2.85	1.12	234^4	3.31	1.30	218^2	3.09	1.22
Grand Rapids, Mich., Miss J. D. Livingston.	153	2.17	0.85	161	2.28	0.90	140	1.98	0.78	151	2.14	0.84
Oxford, Ohio, Prof. S. R. Williams.	149	2.11	0.83	188	2.66	1.05	215	3.04	1.20	184	2.61	1.03
Florence, Ala., Miss E. C. Bellamy.	....	....	....	102	1.44	0.57	113	1.60	0.63	107^2	1.52	0.60
Knoxville, Tenn., Prof. S. M. Bain.	93^3	1.32	0.52	....	....	....	....	....	....	....	....	....
Burlington, Vt., Prof. W. H. Alexander.	157	2.22	0.88	196	2.78	1.09	160	2.27	0.89	171	2.42	0.95
Syracuse, N. Y., Prof. W. L. Bray.	....	....	....	289^4	4.09	1.61	344	4.87	1.92	217^2	3.07	1.21

TABLE I—Continued

Station and Co-operator	May 25 to June 29			June 29 to Aug 3			Aug. 3 to Sept. 1			Average		
	cc.	cm.	in.	cc.	cm.	in.	cc.	cm.	in.	cc.	cm.	in.
Pisgah Forest, N, C., Prof. C. D. Howe.	67[4]	0 95	0.37	70	0.99	0.39	43[4]	0.61	0.24	60	0 85	0.33
St. Annes, Queb., Prof. C. J. Lynde.	171[2]	2.42	0 95	99	1.40	0.55	65	0.92	0 35	112	1 59	0 62
Fredericton, N. B., Prof. C. C. Jones.	94	1.33	0 52	118	1.67	0 66	59	0 84	0 33	90	1 27	0.50
Orono, Me., Prof. W. J. Morse.	120[4]	1.70	0 67	106	1 50	0.59	87	1 23	0.49	104	1.47	0 58
New York, Prof. C. S. Gager.	132[4]	1 87	0.74	148[3]	2 10	0.83	71	1.01	0 40	117	1 66	0 65
Easton, Md., Mr. Henry Shreve.	158	2.25	0 88	229	3.24	1 28	107	1 52	0 60	165	2.34	0 92
West Raleigh, N.C., Prof. F. L. Stevens.	196	2 78	1.09	164	2 32	0.91	74	1 05	0 41	145	2 05	0.81
Gainesville, Fla., Prof P. H. Rolfs	201[4]	2 85	1.12	141[3]	2.00	0.79		.	. . .	171[2]	2 42	0.95
Miami, Fla., Miss Anges Hudson	111	1 57	0 62	144	2 04	0 80	172	2 44	0 96	116	1.50	0 65

were made to derive probable coefficients for the different weeks intervening between calibrations, it being borne in mind that where two cups are in operation side by side, their weekly readings constitute a continual series of measurements of the fluctuations in their coefficients with reference to each other. After the derivation of the coefficients, all readings were corrected and the resulting pair of records (where two cups had operated simultaneously at the same place) were averaged to give the corrected rate for each week and station.

Thirty-eight co-operators in the United States and Canada were provided with instruments. Accidents and interruptions of various sorts occurred, so that the final records are not nearly all complete, but an excellent series of weekly rates was obtained, thanks to the careful foresight and persistence of Dr. Shreve and to the general efficiency of the co-operators at the several stations. There was considerable variation in the date of original installation at the various stations, and some in the date of discontinuance. For the majority of the stations, the available series of readings extends over a period of fifteen weeks, from May 25 to Sept. 7, 1908. In order to indicate the general change in evaporation intensity as the season advances, and not to complicate matters by too much detail, the corrected weekly rates have been averaged in three groups of five weeks each, the averages thus obtained roughly corresponding to the three summer months. The three five-weeks averages have again been averaged to obtain the mean weekly rate throughout the season. These averages, together with the names of the various stations and of the co-operators, are given in Table I. The superscript figures after certain averages denote the number of weeks, if not *five*, and the number of five-weeks periods, if not *three*, from which the average is derived.

Since measurements of evaporation have heretofore usually been made in terms of linear units of depth, the averages from the porous cup atmometers have been reduced to centimeters and inches, and these are also given in the table. In this connection it cannot be too strongly emphasized that no unit of evaporation is of any value unless the surface from which evaporation occurs is accurately defined. (see Plant World 13: 115 1910). In making the reductions here presented, our standard water surface has been that of a nearly hemispherical copper pan 25 cm. in diameter and 12 cm. deep, filled to within 5mm. of the edge at each daily reading. It has been found that the standard porous cup loses one cubic centimeter of water for each 0.1416 mm. of depth lost by this pan, indoors and under summer conditions at Tucson. This constant proved to be 0.137 for the conditions of June, 1909, when the two-foot pan used by the Weather Bureau at Salton, California, was taken as standard for depth measurements. Inasmuch as different pans of water, under different conditions exhibit different relations in their rates of water loss, not only to the losses from the porous cup but also to one another, there seems to be no advantage in considering evaporation measurements in terms of depth, and the criterion in terms of cubic centimeters of loss per time period from the standard porous cup is as satisfactory as any other.

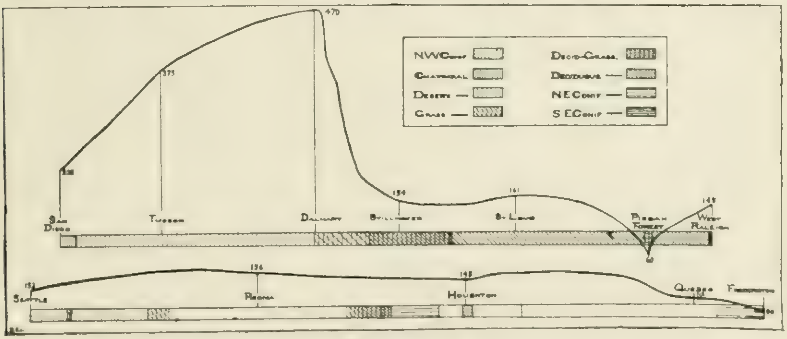

Figure 1

This is especially true when we consider that the cup behaves, as far as the evaporation of water is concerned, more like a plant than does a free water surface, and we are here primarily interested in the evaporating power of the air as it affects plant transpiration.

To obtain a clear picture of the geographical variations in the summer evaporating power of the air, as brought out in the table, reference may be made to the four accompanying profiles (Figs. 1-2) and to the evaporation chart of the United States (Fig. 3.). The profiles aim to present graphically the changes in summer evaporation intensity which would be encountered in crossing the country from west to east and from north to south. The graphs express average weekly loss in cubic centimeters from our standard instrument (the names of the stations are shown above the base line, which represents a rate of 100 cc.), and the amounts for the different stations are placed upon the graphs. Below the base line are indicated, by conventional hatching, the approximate distribution of the main vegetational types of the areas through which a profile passes. Here are considered: the northwestern, northeastern, and southeastern conifer centers; the deciduous forest; the more or less poorly defined belts of transition between the latter and the two eastern conifer areas; a prairie belt or zone of transition from the deciduous forest to the grass land or plains region; the grass land area; the California chapparal and the desert. Our terms are general, our limits merely approximate,and a host of smaller details explainable on the basis of variations in soil, altitude, etc., are here ignored. Information for our present purpose as to the vegetational types and their geographical distribution has been obtained from an unpublished map prepared by Dr. Shreve, which he has most kindly placed at our disposal.

The upper diagram of Fig. 1 represents a profile of the variations in vegetational types and in the intensity of evaporation for the summer of 1908 along a line drawn from San Diego to Raliegh, through Tucson, Dalhart, Stillwater, St. Louis, and Pisgah Forest, the latter station being in the mountains west of Asheville, N. C. In this diagram the highest intensities of evaporation are seen to correspond almost exactly with the limits of the desert region. The California chapparal occupies a strip near the Pacific, with an average rate somewhat above 200 cc. per week. From Dalhart to Stillwater there is a rapid downward gradient in the summer evaporating power of the air,and the vegetation takes the form of prairie, or grassland-deciduous forest transition, with an average weekly rate of from about 150 to 200 cubic centimeters. The change of vegetation to that of the deciduous forest, as we progress eastward, is not marked by any corresponding change in the rates of evaporation, St. Louis, indeed, seeming to possess a somewhat higher rate than Stillwater. With the very marked depression in the evaporating power of the air over the high land at Pisgah Forest, we have a marked alteration in the vegetation, it taking almost the same form here as that of the northeastern conifer center. With the return to an average weekly rate of about 100 cc. the vegetation is again deciduous forest.

The lower profile, Fig. 1, is drawn across the northern limits of the United States and passes into Canada It extends from Seattle to Fredericton, N. B., through Regina, Houghton, and Quebec. The station for the latter place was MacDonald College, St. Annes Although data for an indication of the limits of the different vegetational types along this entire profile are not at hand, it is clear that the highest evaporation intensities accompany the grassland vegetation (this profile does not traverse true desert) and that the lowest occur with either the northwestern or northeastern conifers.

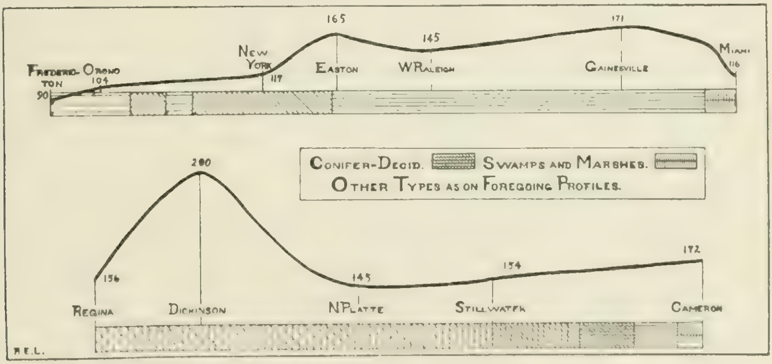

Figure 2

The upper profile of Fig.2, passes from Fredericton,N.B., to Miami,through Orono, Easton, Raleigh and Gainesville. The most striking feature of the diagram is its evidence that the highest summer evaporation intensities occur with the southeastern conifers or with the Florida marshes.

The lower diagram,Fig. 2,is a profile from Regina,Sask,to Cameron, La.,passing through Dickinson, North Platte, and Stillwater The highest atmometric rates, in the north, accompany grassland, being about 150 to 280 cubic centimeters, or above The lowest rates, in middle latitudes, represent roughly the deciduous forest or prairie vegetation; and the somewhat higher rates, at the south occur with the southeastern conifers.

It is hardly necessary to disavow here any attempt at detailed accuracy in connection with these profiles; neither may they be taken to represent what the writer might believe to be the truth, but merely what *appears* from the limited data at hand. Everything considered, however, they probably do not go far wrong, and seem at least worthy of consideration in connection with the various non-quantitative theorizings and rather academic discussions of present-day ecology.

The evaporation chart (Fig. 3) prepared from the fifteen weeks averages of the weekly water losses from the standard porous cup atmometer, may be taken to represent for the summer season, 1908, the variations in the intensity of evaporation over the United States as accurately as the data at hand will permit. The dotted portions of the isoatmic lines on the chart have been tentatively inserted by an interpretation of the humidity chart for the three summer months of the same year, data therefor being taken from the *Monthly Weather Review*. For some reason, impossible of defintiton at present, the evaporation data obtained from Bozeman and Salt Lake City are apparently too low; no commensurately high humidity is indicated for these stations. They have therefore been neglected in the preparation of the chart.

The most significant features of this chart are the following:

(1) The Canadian region of low summer evaporation extends southwestward from Lake Superior, as far as the valley of the Arkansas River. It occupies the northern peninsula of Michigan but not the southern.

(2) Another southern extension of the northern area of low evaporation intensity extends southwestward from southern New England and occupies the whole of the Appalachian mountain system south of Pennsylvania. In the highest mountains, of North Carolina, the average weekly rate is shown to be lower than at Fredericton, N. B.

(3) The valley of the lower Great Lakes is occupied by an area of exceedingly high summer evaporation, which apparently extends, roughly, over eastern Michigan, the penensula of Ontario, and the state of New York.

(4) The southeastern coast exhibits about the same evaporation rates as middle New England, western Michigan, and the Mississippi-Ohio valley.

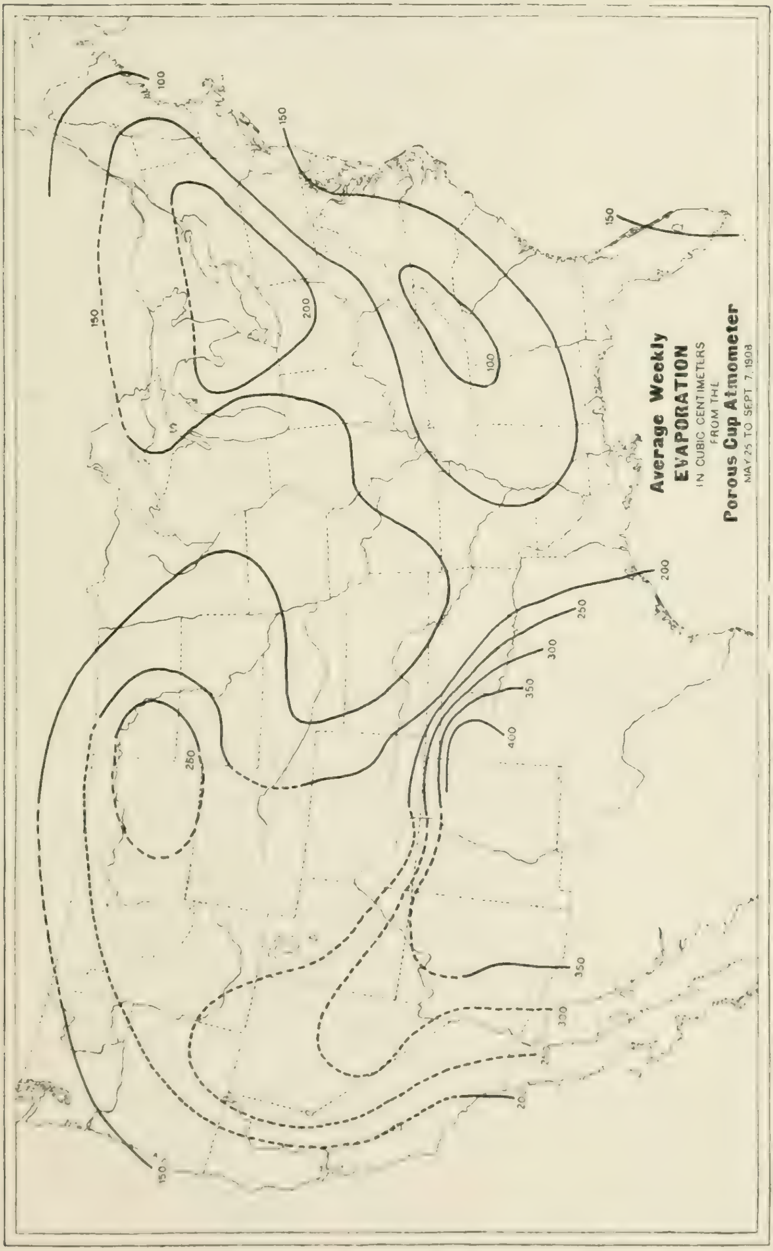
Average Weekly
EVAPORATION
IN CUBIC CENTIMETERS
FROM THE
Porous Cup Atmometer
MAY 25 TO SEPT 7, 1908
100
150
150
150
200
100
200
250
300
350
400
250
350
300
200
150

Figure 3

(5) Westward from a line drawn from Winnipeg, Man., to Corpus Christi, Tex., the rate rapidly rises. The highest evaporation intensity is exhibited by western Texas and New Mexico, and this area is extended northwestward to western Washington, and westward to include the desert of southern California.

(6) San Diego appears to have about the same rate as New York state.

From the information here brought forward, the evaporation rates for a single summer, any attempt to relate plant distribution to this factor in any but a very superficial way would be unfounded, but it is apparent that the northwestern and northeastern conifer vegetational centers are characterized by average weekly rates of less than 150 cc. from our standard instrument,—perhaps about 100 cc. would be a truer limit for the northeastern center. The well-known southern prolongation of the northeastern center in the eastern mountains is clearly paralleled on the evaporation chart. The deciduous forest of the middle east occupies a region with over 100 cc., often over 150 and even 200 cc., as the mean weekly summer rate. The southeastern conifer center occupies the southern part of the evaporation area which is characterized by rates of from 100 cc. to 200 cc. Summer evaporation alone can not explain its existence as a distinct vegetational type. The generally cultivated area of Oregon and California appears to have summer rates of 150 cc. to 200 cc. per week, and the great arid region is clearly indicated by our atmometric data. The prairie region appears to be climatically a *potential deciduous forest*, as is suggested by the success which has attended tree planting in Iowa, eastern Nebraska, eastern Kansas, etc., as well as by other considerations. The grassland represents the transition from the evaporation conditions of the deciduous forest center to those of the arid region.

It will be interesting to apply the method used in 1907 to the evaporation rates as exhibited by the northeastern conifer, the deciduous and the desert regions for the summer of 1908. Inspection of the map leads us to set the average summer (1908) evaporation rate for the northeastern conifer area at about 100, that for the deciduous forest at about 175, and that for the desert region at about 350 cc. per week. The reciprocals of these rates are 1.00, 0.57, 0.29, to compare with 1.00, 0.84, 0.16, from our summer approximations of 1907, and with our approximations from Transeau's annual ratios, 1.00, 0.86, 0.35. It is apparent that the agreement between the annual index (from Transeau's ratios) for the deciduous forest center (the index for the northeastern conifer area being assumed as unity) is in much closer agreement with that for our first summer approximation than with that for 1908, while the annual index for the desert region agrees more satisfactorliy with our summer index for 1908 than with that for the previous summer. Such a condition seems to exhibit the low degree of detailed accuracy which may be possessed by any method which depends upon climatic data for a single year; it is practically certain that such indices as we have used must fluctuate between wide limits in different years. Transeau's ratios, while calculated form the data of mean annual precipitation based upon observations for many years, also involve the evaporation rates for a single year, as obtained by Russell in 1887 and 1888, The time for nice quantitative distinctions and critical study in these matters has obviously not arrived.

From the above general deductions it is apparent that the summer evaporation intensity alone furnishes a climatic criterion for studying the different vegetation centers with which we have to deal at least as promising as the criterion furnished by any other meteorological element. Summer evaporating intensity while exhibiting relations not in detailed agreement with those shown by the annual rain-evaporation ratios of Transeau, may be considered of as great promise in this general problem as are the latter; the fact that the annual ratios and the two series of summer data are all for different years might give as discordant results as we have obtained, even though the mean intensities for an adequate period of years might still show agreement. The summer data, especially if obtained by some such means as ours, offer much less difficulty in their derivation than do these used for the annual ratios, so that there may be more hope of getting an adequate series of them to extend over a number of years. The importance of the relative intensities of evaporation, to ecology and agriculture, are only surpassed by the present dearth of information in this connection, and it may be regarded with some surprise that two decades intervened between the dates of the first and second attempts to prepare an evaporation chart of the United States. As soon as the fundamental problems of agriculture attract public and scientific attention, it is probable that evaporation measurements may become a prominent feature in climatological and phenological work.

The Johns Hopkins University.

SOME BOTANICAL OBSERVATIONS IN THE MOUNTAINS OF WASHINGTON.

A. S. FOSTER.

The region in which the observations have been made which are recorded here, is a huge triangle,—or more nearly the face of a vast pyramid,—the western edge of which is the Nisqually Glacier, the source of the river of that name, the eastern edge the Paradise Glacier, and its eastern lobe the Cowlitz Glacier, while its southern edge is formed by the summit of the Tatoosh Range, the highest peaks of which attain 6,500 to 7,200 feet altitude. Within this area are numerous mountain torrents, deep canyons, escarpments, snow fields, mountain meadows, orchard-like groves, springs and lakes. The Paradise River traverses the triangle, with a southwesterly course of some six or eight miles within which it falls about 4,000 feet, plunging over the rim of the snow field as Shuskin Falls, and further down dropping 150 feet in the beautiful Narada Fall. From whatever part of this area one may look there is a grand panorama of snow-clad peaks, including Mt. Adams, St. Helen's, and Mt. Hood.

My visit to this region was made in the ten days following August 3, 1909, during which time the atmosphere, usually clear, was made very smoky by distant forest fires. A month earlier the snow had been ten feet deep in many places, and large drifts were still to be seen in sheltered spots. Heavy frost occurred on every night excepting those on which a penetrating fog enveloped the mountains.

The lower portion of this triangle is—or was not long since—a continuous coniferous forest in which the Douglas Spruce and Hemlock, *Tsuga heterophylla*, range upward and mingle with *Abies lasiocarpa*, *Tsuga Mertensiana* and the less frequent Alaskan Cedar, *Chamaecyparis nootkatensis*. The chief undershrubs in this forest are *Vaccinium ovalifolium*, *V. deliciosum*, *V. macrophyllum*, *Azaleastrum albiflorum* and *Menziesia glabra*, while along the streams grow *Salix Geyeriana* and *S. tenera*. *Vaccinium ovalifolium* was in abundant fruit during my visit, and the *Azaleastrum* in full flower. The willows were just beginning to flower on August 4th, and by the 12th they were in full leaf. Common among the herbaceous plants of the forest were *Pyrola rotundifolia*, *P. bracteata*, *Streptopus roseus*, and *Gaultheria ovalifolia*, while in the open timber *Erythronium montanum* and *Clintonia uniflora* were in full bloom. *Polystichum munitum* was found in these forests growing to a height of a few inches, in strong contrast to the individuals of this species several feet in height that had been observed at lower altitudes. Near the Narada Falls *Phegopteris Dryopteris* was common and also *Cornus canadensis*, while at the bases of the trees the liverwort *Ptilidium Californicum* grew luxuriantly. All of the above mentioned groups of plants may be found on the coast of Washington, where the climate is moist and never very hot, and here they reappear in the higher mountains near the transition from the Canadian to the Hudsonian zone.

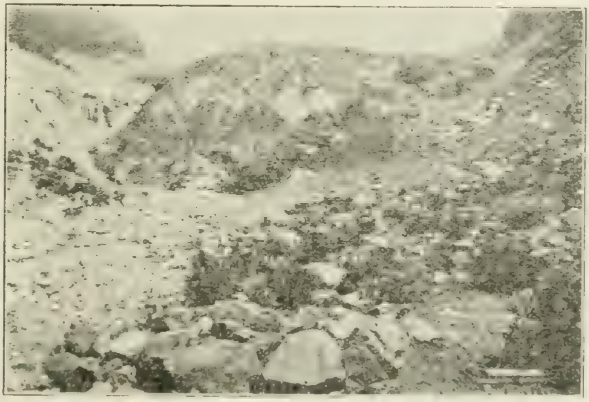

Fig. 1. The foot of the Misqually glacier and source of Misqually river

On climbing out of the valley of the Paradise River one comes into stretches of open park-like forest with a floor of meadowy character. Over this region heavy snowfall often occurs as late as the first week in July, while at the Inn at 5,820 feet altitude frost occurs on every calm night throughout the summer. On the morning of August 8th we observed plants of *Xerophyllum tenax*, *Pedicularis bracteosa* and *Ranunculus Suksdorfii* which had been thawed by the early morning sun and were limp from frost. The cold air currents that flow down the mountain slopes during the night are followed by midday temperatures of 75 degrees to 80 degrees, changes which follow so rapidly that plants frequently perish for lack of water. The principal trees in these park-like forests are the Fir and the Hemlock. They reach a height of from forty to eighty feet, and branch from the ground up with a spread of limbs of no more than ten feet. These trees commonly grow in groups of four or five to fifteen or twenty, and this habit is also characteristic of the shrubs, including *Pyrus occidentalis*, *Phyllodoce empetriformis* (the red heather), *Pachistima myrsinites*, and *Spiraea densiflora*. The Willow of these altitudes, *Salix tenera*, and the Alder, *Alnus sinuata*, are found only in the most favorable situations. One of the hardiest of the herbaceous plants is *Pulsatilla occidentalis*,

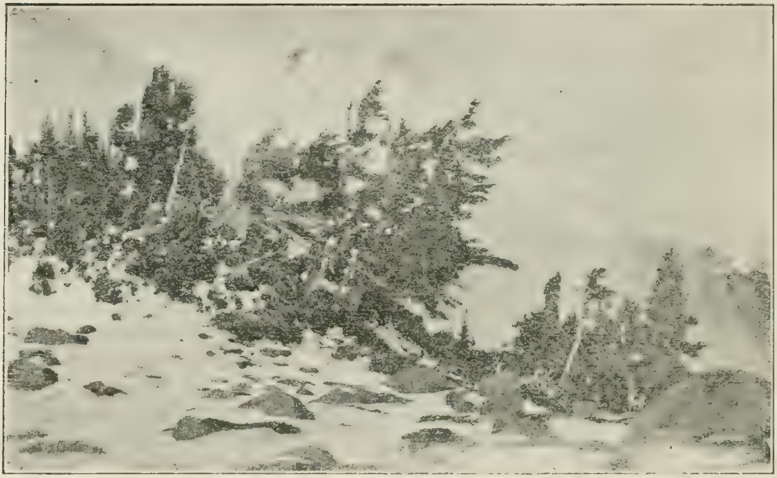

Fig. 2. *Tsuga Mertensiana* and *Chamaecyparis nootkatensis* near timber line

which has a large root system, and is one of the earliest plants to break through the remaining crust of snow. When three or four inches in height it blooms, after which a single very tomentose leaf is developed, followed successively by another flower and a second leaf. Along with the *Pulsatilla* grow *Lupinus Lyallii, Polygonum bistortoides, Senecio triangularis, Oxyria digyna, Epilobium alpinum, Leptorrhina amplexifolia, Poa alpina,* and numerous other grasses, sedges and junci, all extremely depauperate in size.

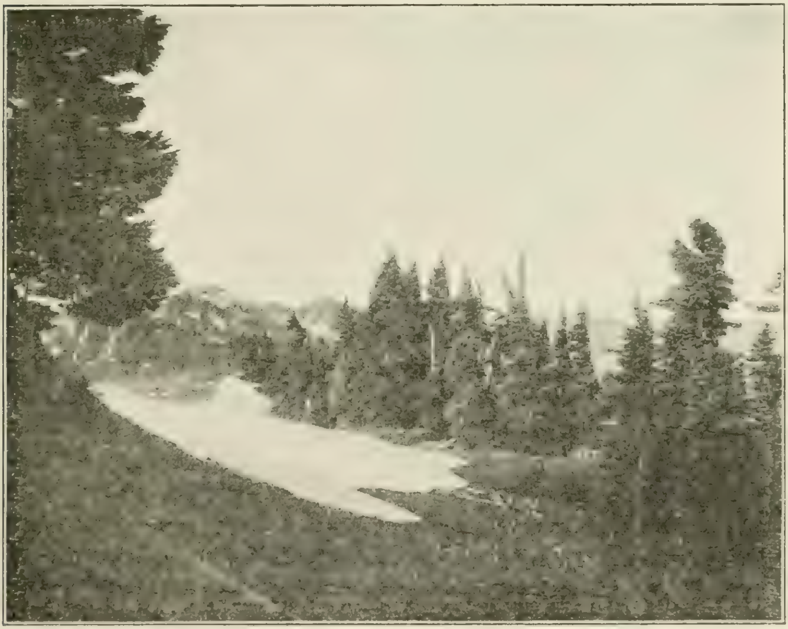

Fig. 3. The Tatoosh Range as seen from Paradise Park. In the foreground *Tsuga Mertensiana* and *Abies lasiocarpa*.

The effects of wind and snow on the vegetation are extremely manifest at these higher altitudes. What the greatest depth of snowfall is I was unable to learn, but all of the herbaceous plants of the preceding season are pressed quite flat to the ground, and moreover show the down-hill movement of the snowbanks. Indeed the largest trees are seldom without a crook at the base resembling a sled runner, and doubtless due to this same cause. The winds, strong even in summer, are responsible for the procumbent habit of many plants. *Juniperus communis* is common on the ridges, and may often trail the ground for eight or ten feet without reaching a height of that many inches. On the peaks and ledges at 7,000 to 8,000 feet the Alaska Cedar is only semi erect or completely prostrate, growing in crooked, gnarled form, with a spread of twice its height. Only two specimens of *Pinus albicaulis* were seen, both of which were dwarfed, although this species reaches a height of ten feet on Mt. Hood at these altitudes. Even such herbaceous plants as *Phlox diffusa, Leutka pectinata, Pyrola secunda*, and *Poa arctica* are found only prostrate in habit on the ridges and wind-swept ledges.

The southwest wind of summer is responsible for small sand drifts, which are colonized by the shrubs and trees, while the snow movements of winter accumulate beds of shale in which I have found *Empetrum nigrum, Pedicularis racemosa, P. bracteosa, Aster integrifolius, Antennaria rosea, Saxifraga Bongardi, S. Tolmiei*, and *Phyllodoce glanduliflora.* The surface of the larger rocks is covered with the crustaceous lichen *Lecanora foveolaris* forma *dealbata,* and in the crevices of the rock grow *Pentstemon Menziesii, P. procures, Sibbaldia procumbens* and *Saxifraga odontoloma.*

Pinnacle Peak, 7,200 feet in altitude, was scaled on August 7th, and on this highest point in the Tatoosh Range dwarfed Alaskan Cedars were found in the crevices of the rocks, and about them a very interesting assemblage of plants. Among these were *Linnaea americana, Erigeron aureus, Sedum divergens, Cheilanthes Feei*, and *Cryptogramma acrostichoides*, the last of which also grows among the cobbles of the beach at Seaside, Oregon. Among the lichens which endure the tremenduous range of conditions on this peak are *Parmelia lanata, P. tristis, P. stygia, Gyrophora hyperborea, G. vella, Cetraria icelandica,* and *C. Fahlunense.* Also of great interest in the cryptogamic flora is the Red Snow, *Sphaerella nivalis*, which frequently turns the remaining banks of snow a brilliant red, giving a very pleasing touch of color to an otherwise austere landscape.

On the more exposed slopes where the wind prevents the heavy accumulation of snow and the sun first melts that which remains in the spring, the vegetation is heavier and more varied than elsewhere. The level depressions are also heavily covered with grasses, sedges, and rushes. A number of interesting ferns, mosses and lichens were found in these situations and in the so-called "pumice fields." Among the debris of the slides in the pumice fields were found *Polytrichum piliferum* and *P. gracile*, and in the midst of the larger boulders of the lateral moraine of the Nisqually glacier *Polytrichadelphus* was discovered, a rare alpine form. The sharp angles and edges of boulders in open situations are colonized by *Buellia geographica*, and with it *Grimmia Muhlenbeckii* is extremely common. We also found *Rhacomitrium Macounii* on wet ledges of rock about the boulder fields, and *Rhacomitrium* has also been collected in this vicinity. Immature specimens of *Gyrophora* were collected at Gibraltar Rock, altitude 12,000 feet, and *Placodium elegans* at Camp Muir at 10,000 feet. Indeed, this is practically a virgin field for the bryologist, and among the thirty-five species which I collected were such rare forms as *Eustichia Norvegica* and *Pseudoleska radicans*, and the Arctic forms *Andreaea alpestris*, *Grimmia ovata*, and *G. manniae*. Some fifteen species of liverworts were collected also, including *Jungermannia Allenii*, *Nardia Brideleri*, *Hygrobiella laxifolia*, *Marsupella Sullivantii*, and *Targionia hypophylla*. Among the ferns some seven forms were collected, including, in addition to those already mentioned, *Polystichum lonchitis* and *Polypodium hesperinum*. Such a rich and diversified field well deserves more thorough exploration.

Pacific Beach, Washington.

BOOKS AND CURRENT LITERATURE.

GEOGRAPHICAL STUDIES IN PALESTINE.—Students of plant geography are greatly indebted to Professor Huntington, of Yale University, for his extended studies of desert conditions in connection with climatic changes. In the course of these changes, whether in historic or prehistoric times, there can be no doubt that the plant life of various arid and semi-arid regions of the earth's surface has undergone profound modifications, but our knowledge has hitherto been so inexact as regards the actual climatic conditions even of relatively recent periods,—say from two to three or four thousand years ago,—that any correlation of the phenomena of plant distribution with changes of climate in late geological times has been an extremely hazardous undertaking, and such attempts, while fascinating, have been liable to a very high degree of uncertainty. There is no doubt that when the data are all in the problem will still present many, in some cases possibly insuperable, difficulties, but it is certain that in such work as Dr. Huntington has been doing in Central Asia, in Palestine and in the south-western United States the foundation has been laid for a far more definite knowledge of the phytogeogeography of these regions from a historical point of view than has hitherto been attainable. His work on Palestine* is a specially noteworthy contribution in that, as pointed out by the author, climatic variations (with consequent changes of vegetation) would there produce notable variations in habitability, while at the same time its known history extends back to remote antiquity. Such a study as this, therefore, which was carried out by the Yale Expedition in 1909, might reasonably be expected to throw a considerable amount of light on the problem of climatic (and therefore vegetational) changes in Palestine during the period covered by recorded history.

Although many, perhaps a majority of geographers and historians assume that climatic changes within this period are of negligible importance, the author shows, as it seems with convincing proof, that the climate of the region investigated has been subject in the course of the past five thousand years to numberless changes and that these have been a potent factor,—largely or chiefly through their effects on vegetation,—in the guidance of some of the greatest historical movements. Omitting through sheer necessity all discussion of this most fascinating part of the work, reference may be made to certain facts of special interest to students of plant geography.

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*Huntington, Ellsworth. Palestine and its Transformation. Houghton, Mifflin & Co., Boston and New York, 1911.

American botanists who are familiar with the southwestern United States will be interested in the striking comparison of Palestine with southern California. In the latter, from Los Angeles fifty miles north-eastward across the mountains to the Mojave Desert the same marked and rapid changes are observed as in the same distance from the Meriditerranean to the Dead Sea. "The immediate coast of California is cooler than that of Palestine . . . . but the orange groves at the foot of the mountains correspond to those of Jaffa, the grain fields in the upland valleys are not unlike those of Judea and the Mojave Desert at the eastern base is of the same type as that which surrounds the Dead Sea." What southern California would be without irrigation may be pictured in part from the present condition of Palestine. The latter country, like the former, lacks summer rains, and if the winter rains are either late in bebinning or cease too early, a famine is the likely result. The inevitable outcome of such untoward conditions, which as shown by the author have become greatly accentuated within the historical period, is seen in a great decrease of productivity of the soil, the disappearance of olive orchards and vineyards from the terraces they once occupied and the loss from the landscape of noble oaks and other trees that gave the land so much of its beauty in the days of psalmist and prophets.

The evidence for these conclusions is cumulative, and those who would feel its full force must follow the author in the graphic story of his journeys from the Dead Sea and the Negeb to Lebanon and Palmyra, and in his masterly presentation of physical and historical data. To those who have read "Cosmos," or any other monumental "shy at the universe," with resulting weariness of soul, or have found it an ungrateful task to read "The Land and the Book" and other works which use the physical features of Palestine merely as confirmation of biblical narrative, this book of Huntington's will prove a double treasure, rigidly scientific in its methods and conceptions and at the same time broadly hospitable to every form of truth that history or tradition have brought to light. Botanists who have occasion to draw conclusions regarding plant life in arid or semi-arid regions will find it essential to become conversant with the author's arguments and conclusions, which seem likely to lead to important modifications of doctrines that have been widely held and taught.—V. M. SPALDING.

NOTES AND COMMENT.

The results of a careful examination of the histological relations of *Cuscuta* and *Salvia*, one of its hosts, has been published in a recent number of Annals of Botany (July, 1911) by M. G. Thoday (nee Sykes). The lack of understanding of the actual physical relations of plants displayed in this article may be best illustrated by the following citations from the summary: "The protoplasm of the parasite is easily shrunk away from the sieve area, and is probably never closely fused with the host protoplasm. The translocation of food-substances from host to parasite would appear to be of the nature of passive filtration, the contents of the sieve tubes, forced by internal pressure, escaping through the lateral sieve fields into the parasite. This arrangement probably disturbs as little as possible the normal mechanics of the sieve tubes of the host and ensures for the parasite a long-continued supply of nutriment." Further "That the parasite takes so much trouble to make use of the host sieve fields as they are, and not to disturb the mechanics of the sieve tubes, is important testimony in favor of the functional efficiency of sieve tubes in general and sieve fields and sieve plates in particular." These statements are abundantly refreshing both as to literary construction and as to scientific point of view. The actual work on which they are based was well planned and lacks nothing as to thoroughness and exactness. The advance of knowledge concerning hydrolysis and kindred processes has made possible a substantial addition to the earlier results on the subject, published by Peirce in 1893 and 1894.—D. T. M.

Professor Adolfe Prunet, Associate Director of the Agricultural Experiment Station of the University of Toulouse, has been attempting for several years to work out methods for attacking problems in plant pathology that would furnish a sound, scientific basis for dealing with plant diseases. A summary of his "method échelonnée" was presented before the French Academy of Sciences (12 June, 1911).

In studying the Black-rot of the grape-vine, he divided the fields in which the experiments were to be made into a number of lots, each with one or two vines. As soon as the young leaves began to break out of the buds he treated one lot with Bordeaux mixture, and each day (or every other day) after that one lot was sprayed. The dates of the applications were recorded, and the first appearance of the black-rot was noted. In 1899 this was on the 16th of May. Every lot had been sprayed; those that had been sprayed between the 19th and 25th of April escaped the disease; all the others were attacked. The plants treated between these two dates escaped because the treatment prevented the germination-tube of the black-rot spore from entering the leaf. The application after the 25th of April was not efficacious because the infection was already complete. This method allows the experimenter to determine the date of the infection and duration of the incubation period—that is, the time between the entrance of the fungus into the leaves and the breaking out of the rot upon the surface. The stages in the development of the parasite upon the host up to the time of sporulation were also marked off by this method, and these stages were then correlated with the meteorological conditions, so that the role of the atmospheric factors in the development of the disease could be determined. These methods enabled Professor Prunet to determine the period favorable for efficacious spraying, beyond which the spraying was of little or no use. His results also served to explain the conflicting experiences of various vine growers with Bordeaux mixture. The method of investigation is of general application and has been used in dealing with mildews and the destructive "cochylis" (*Conchylis ambiguella*).

A similar method was used in researches upon a wheat rust, against which spraying with copper mixtures was of no avail. The wheat was planted in pots in protected green-houses of the Botanical Garden. Every day two or three pots were transferred to the fields where the wheat was badly rusted. As soon as any of the experimental plants showed the contamination, the date of infection as well as the period of incubation were determined. This method also enabled Professor Prunet to determine that the infection always coincides with rains or heavy fogs.

As a confirmation of his conclusion, the reverse of the above method was used. Wheat was planted in pots in the field, and each day two or three pots were removed to the green-houses. The results of the two series of experiments agreed completely. It is hoped that as result of such experiments there will be developed a solid basis for vegetable pathology and therapeutics.—B. C. GRUENBERG.

We are in receipt of the first issue of *The Journal of the Washington Academy of Sciences*, a semi-monthly publication devoted to brief articles and to abstracts of work done by men in the scientific bureaus of the government. The *Journal* is apparently destined to fill such the same place among physicists and chemists that *The Experiment Station Record* does among botanists and agriculturists. It does not fail, however, to contain much that will interest botanists in its abstracts of work in forestry, meteorology, physiography and paleontology. In these days we naturally crave the journal in which the contributions are short and to the point, and in which the reviews and abstracts are numerous and are discriminating as well as informing.

Volume 14 Number 10

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

OCTOBER, 1911

SOME ALASKAN AND YUKON RUSTS.

J. C. ARTHUR.

Very little is known of the uredineous flora of Alaska. The most extensive series of specimens yet reported is that made by the Harriman expedition of 1899. Forty species were listed,[*] largely collected and determined by Dr. William Trelease, Director of the Missouri Botanical Garden. All but two species(three collections) of the list were secured along the southern border of Alaska and the Aleutian Islands. The two exceptions are *Puccina laurentiana* Trel., on *Saxifraga*, and *Melampsora alpina* Juel, with I on *Saxifraga*, and II (III) on *Salix* (the I being listed as *Caeoma saxifragarum*), both obtained from the northern part of Bering sea. Besides this series only occasional specimens have come to hand in various ways, and practically all from along or near the southern sea-coast.

During the summer of 1909 an extensive collecting trip was made through the interior of Alaska by Prof. A. S. Hitchcock, agrostologist of the U. S. Department of Agriculture. Although devoting his attention primarily to the grasses, he secured a few excellent specimens of rusts, which he kindly turned over to the writer for study. All, with two exceptions, the aecia on *Ribes* and uredinia on *Ledum*, belong to species not listed by Dr. Trelease in the Harriman report. Only three localities are represented by the collection, but these three localities are long distances apart and are typical of as many highly distinct climatic regions: the temperate region along the southern sea-coast, the interior arctic region about Dawson, and the coast arctic region near Bering strait. It is noeworthy that none of the species

[*] Alaska: the Harriman Expedition 5:36–41. 1904.

can be said to be strictly arctic, although mostly preferring boreal or mountanous habitats. The following is the list of species, given in regional groups.

1. SOUTHERN COAST SPECIES, collected at Sitka, June 21, all in the aecial stage only.

Puccinia Grossulariae (Schum.) Lagerh. (*Aecilium Grossulariae* Schum.), on *Ribcs laxiflorum* Pursh. This is probably one of the racial forms belonging to the abundant cosmopolitan rust with telia on various species of *Carex*. The exact status of the form must await knowledge derived from cultures. Similar collections have been made along this coast by a number of collectors.

Puccinia Veratri Duby, on *Epilobium adenocaulon* Hausskn. This heteroecious species, cultures of which were made by Tranzschel in 1908, has not before been reported north of Glacier, B. C., for either aecial or telial stages, the latter being on species of *Veratrum*.

Aecidium sp., on *Petasites frigida* (L.) Fries. The host was determined by Mr. W. F. Wight, November, 1910. This rust is seemingly identical with the aecia on *Tussilago Farfara*, which is known to be the aecial stage of *Puccinia Poarum*, having telia on species of *Poa*. Repeated trials by Tranzschel, however, have failed to infect *Petasites officinalis* by sowing teliospores from *Poa*. This does not preclude the Alaskan rust from belonging to the *Poa* combination, nevertheless, for the habit and texture of *Petasites frigida* are much like those of *Tussilago Farfara*, while *P. officinalis* is a quite dissimilar plant. Other collections of the same rust have been made in Alaska on *Petasites corymbosa* (R. Br.) Rydb. by J. M. Macoun at St. George Island in 1891, and by C. V. Piper at Kadiak in 1904.

2. INTERIOR ARCTIC SPECIES, collected July 17-19 at Dawson, Yukon territory, a little north of the 64th parallel of latitude, and about 300 miles from the southern sea coast. Dawson is close to the eastern boundary of Alaska, and less than 150 miles from the Arctic Circle. Its boreal and interior position give the collections unusual importance, and especially as these are the first rusts to be recorded for all this great interior territory, so far as the writer knows.

Puccinia rubefaciens Johanns., on *Galium boreale* L., a rust common to both hemispheres.

Aecidium Allenii Clint., on *Shepherdia canadensis* (L.) Nutt. This is a heretoecious form of wide distribution in North America, and probably belongs to some grass rust, indications pointing to an unnamed form on *Calamagrostis*, *Agropyron* and *Bromus*, but no cultures have yet been made. The most northern station heretofore known for it is Banff, Alberta.

Melampsora Ribesii-Salicum Bubák (*Uredo confluens Pers.*), II on *Salix glauca* L. The host was determined by Dr. F. V. Coville, November, 1910. This is probably a common and widely distributed species, but very few sporophytic collections can be referred to it with certainty. It is a mountainous form extending through a wide range of latitude in both the Old and New World. The specimen in hand is scanty, but seemingly characteristic.

Melampsoropsis ledicola (Peck) Arth. (*Chrysomyxa ledicola* Lagerh.), II on *Ledum groenlandicum* Oeder. This abundant American rust has been collected on the same host in Greenland (in 1886), and at Fort Wrangell, Alaska (in 1883, by Thomas Meehan), and also on *Ledum palustre* at Turnavik island, Labrador (in 1896, by the Cornell-Peary expedition), and at Virgin Bay, Alaska (in 1899, by Wm. Trelease of the Harriman expedition). It is evidently a common Arctic species, ranging south to the northern border of the United States.

Peridermium boreale Arth. & Kern, on *Picea candensis* (Mill.) B. S. P. This little known and ill defined species has not before been reported north of Banff in British Columbia. The leaves on the specimen have fallen from the stem in drying, but otherwise the collection is typical of the species.

3. COAST ARCTIC SPECIES, collected between Aug. 20 and Sept. 1 at Nome, less than a hundred and fifty miles south of the norrowest part of Bering strait. This is within the region from which *Puccinia laurentiana* and *Melampsora alpina* have been reported as mentioned above.

Puccinia septentrionalis Juel. II and III on *Polygonum viviparum* L. This species has also been found in Newfoundland by Rev. Waghorne, and its aecia, which occur on *Thalictrum alpinum*, were collected July 28, 1904, at Kadiak, on the southern coast of Alaska, by C. V. Piper, no. 4474. These are the only American stations so far definitely known for the species.

Puccinia Gentianae (Str.) Link, i, III on *Gentiana frigida* Haenk. The specimen is especially interesting as it shows a few well developed aecia and an abundance of telia, while no urediniospores were to be found. The microscopic characters agree with more southern collections in which urediniospores are usually in the majority, but the aecia rare.

Puccinia ? sp., II on *Arctagrostis arundinacea* (Trin.) Beal. This rust in its uredineal form is so much like *Puccinia pygmaea* Erikss., on *Calamagrostis epigeii*,occurring in Sweden and Finland, that it would have been referred to this species but for the following reasons: The uredinial sori of this species are much larger and more conspicuous, being darker in color, than those of the European form; they are also amphigenous, while the European form is chiefly on one side of the leaf. The urediniospores in the American form have somewhat thicker walls, and somewhat more numerous and far more evident germ-pores, than in the European form. The paraphyses are also strongly capitate and much thickened above in this specimen, while in the foreign ones they are chiefly clavate with a wall of practically uniform thickness throughout. These differences, and the total absence of telia, make it unwise to list the collection as *Puccinia pygmaea*, although it seems to be closely related, possibly the same. It is the first collection of the kind from America or elsewhere.

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CHANGE OF ASPECT WITH ALTITUDE.

J. C. BLUMER.

The striking dissimilarity of the species growing upon two slopes opposing one another in the general direction of a meridian is well known, because easily observed. Much more elusive is the fact that the same species changes its aspect, or slope-exposure, from north to south in rising from its lower to its upper altitudinal limit. In a previous paper * the writer noted the behavior of *Lippia wrightii* in this respect. Since then other species of the desert mountain ranges of Southern Arizona, have been found to exihibit the same distributional character.

The second plant found to behave similarly was *Calliandra eriophylla*. On Tumamoc Hill, near Tucson, this dwarf shrub is found sparingly in places of good soil moisture conditions, preferably on north aspects. It is more adundant on rocky north slopes in the foothills of the Tucson mountains, associating with *Selaginella*. One thousand feet higher, as for instance near the Sierrita Mountains, and in similar country of the same altitude elsewhere, it spreads abundantly over the plains and foothills. Rising another thousand feet, it was found in the Oro Blanco Mountains on the timberless south side of the high hills, often coming well down into the oak scrub, but leaving the opposite side to the oaks. Similarly, at the same elevation of 4,500 feet in the Santa Rita Mountains, it is associated with *Mimosa dyscoarpa* on a slope falling southward into Sawmill Canyon, while the north side of the ridge is given to the oaks and *Nolina*.

The herbaceous perennial *Perezia wrightii* is found on the north slopes of Tumamoc Hill at an elevation of 2,500 feet, a closely related plant (*P. thurberi*) was found in the Chiricahua Mountains at 5,800 feet elevation at the southern base of a cliff. Equally infrequent as in the preceding locations, the latter was encountered in the Rincons at 4,900 feet on a west slope.

Although annuals are frequently of wider vertical distribution than perrennials,and not so closely limited to special habitats, a similar case appears to be found among the former in *Lupinus leptophyllus*. Near Tucson it is abundant on the north side of Sentinel Hill, but absent from the south side. In the the Oro Blanco Mountains, it was seen growing on the south side of mountains near 5,000 feet, and collected on canyon bluffs of similar aspect at about 4,000 feet just acrosss the International Boundary.

In the Santa Catalina Mountains, decending from Oracle Ridge on the Leatherwood Trail, on a slope of schistose granite, the physiognomy of the forest growth on a protected southerly aspect is similar to that of a more open, easterly one a few hundred feet farther down. An open forest of the Arizona pine is undergrown with whiteleaf oak (*Quercus hypoleuca*), a tall, vigorous shrub, and sometimes a shapely tree as high as fifty feet. A few netleaf oaks (*Q. reticulata*) and manzanita (*Arctostaphylos pungens*) are present, and a rather large number of madrone (*Arbutus arizonica*) are conspicuous as tall shrubs or gnarled trees. The otherwise unoccupied interspaces are largely taken up by coarse mountain grass (*Epicampcs ligulata*) and low, thorny underbrush (*Ceanothus fendleri*). Where the pine stands more closely, *Muhlenbergia gracilis* takes the place of many shrubs, and immediately across a V-shaped gully, with a northeast instead of southeast aspect, this grass and the pine have almost displaced the shrubbery and the other grass, and the transition is strikingly complete. This is but one example of what may be constantly observed in aspect relations, whenever the opposing slopes extend in a more or less east-west direction laterally. We need only to climb 1,000 feet to the vicinity of Mount Lemmon,to find the same grassy pine forest of the above noted northeast gully slope on a mountain side facing in a southerly direction.

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*Plant World, XI, p 117, June, 1908.

In the Santa Rita Mountains a number of the characteristic plants change their aspects between the lower and upper limits. In ascending by the way of Stone Cabin Canyon, netleaf oak (*Quercus reticulata*) is first found in shaded gullies and strictly north acclivities at about 6,000 feet It becomes more common upward in company with the whiteleaf oak (*Q. hypoleuca*), which appears about the same time in similar places. At 6,500 feet it was seen to assume tall,clean,coppice form about twelve feet high, in the gulches frequently with large, obovate, flat leaves. Ascending, it increases in abundance, spreading now over east and west slopes. Upon reaching Horse Ridge which extends east and west at the head of the canyon at an elevation of 8,000 feet,it is practically absent from the north side, on the south side however,it is seen to mix freelywith the other two oaks (*Quercus hypoleuca* and *Q. arizonica*), displacing them more and more as the stuation becomes higher, steeper, more rocky and exposed. At length the other two are left behind, the netleaf oak is the typical chaparral growth under the scattered pines, sometimes dense, again very open, all the way to the high summits on all southeast, south, and east aspects, reaching the ultimate summit of Mt. Wrightson within a few yards of its height of 9,432 feet above sea. On the northwest side of what once may have been a crater's rim it is absent, and on certain parts of this elevated and extremely sharp crest extending a little east of north, it is cleanly replaced by a deciduous oak (*Quercus submollis*) as soon as the edge is crossed. Here we see *Q. reticulata* always with the small, revolute, oblong leaf and small stature, dwindling to less than two feet on the summits.

This change of aspect is equally well exemplified in the occurrence of other oaks, and to a lesser extent also in their change of form. Arizona White Oak (*Q. arizonica*) appears first in the Upper Sonoran zone, on the north side of a ridge lying at an altitude of about 4,500 feet near the McBeth ranch. but is entirely absent from the grassy south side. Thence upward, as usual, it is almost everywhere present, linking the Upper Sonoran and Transition zones, and at about 8,200 feet its uppermost outposts finally disappear from a southeast slope. It undergoes a change of form with ascent, from the size of a tree with large, obovate, often toothed leaves, frequently found in the lower gulches, to small but always erect brush form, growing five or six feet high in mixture with other shrubs, bearing a smaller, thinner, more oblong, less coriaceous leaf. Many slight variations occur in this oak, here as elsewhere, but in this region the transition from one form to another is usually so gradual as to escape notice in the field, making it an unquestionably homogeneous species. So that any ill-founded segregates that might be made would not disturb the unity of type for purposes of the present comparison of its different aspect habitats. The same may be said of the other, less variable,and very distincet species of oak.

The whiteleaf oak, in the Stone Cabin Canyon, likewise makes its first appearance on north slopes, with the advent of the Transition zone, it is heavily represented thence upward, especially in the cooler, better protected gulches, where it produces tall, vigorous shrubs with stems of post size, and often fine, tall trees. It becomes general on various aspects, but is almost displaced by the Douglas fir on the north side of Horse Ridge.

On the south side it reappears in abundance, and much reduced in size. At an altitude intermediate between the upper limits of the two preceding species, it is last seen on the same open southeast mountain side where *Q. arizonica* dsappears. Here it is an erect shrub of about the height of the latter species at its upper limit, with smaller leaves than below, and these more compactly placed. Both species are strictly absent on a northeast aspect just over the crest of a sharp, sloping ridge. As before, at least where the presence of rocky outcrops favors it, the deciduous white oak chaparral (*Q. submollis*) appears here.

Similar features of local distribution, only less well marked, are shown by the conifers. The Douglas Fir (*Pseudotsuga taxifolia*) on the very steep northerly declivities toward the bottom of Stone Cabin Canyon must reach down to within 6,000 feet of sea level at most. It reaches its local center of density, as a fine forest, in the cool, hanging gulches draining northward at about 8,000 feet, but at 9,000 feet it appears to some extent on east and west as well as north aspects. Here it is rather scarce once more, probably due less to high elevation than to the unusually exposed and semi-arid character of these rhyolitic heights.

Mexican white pine (*Pinus strobiformis*) was first encountered at a spring in the bottom of a gulch at 6,500 feet. A few hundred feet higher it first appeared away from water on a steep slope of north aspect,while strictly absent on other aspects. It increases upwards and on the highest peaks it ranks with *P.arizonica* in numbers,or even exceeds it. While here it still prefers the slopes and pockets at the base of cliffs facing toward the north, it can be found in almost any other situation. The Mayr pine (*P. mayriana*) was noted at 6,500 feet, mixing with the Arizona pine on similar north-facing habitats. On the sunny, south side of Horse Ridge, at 8,000 feet, a few trees were seen again that probably belonged to this sparsely represented species.

The principal pine of the forests of southern Arizona (*P. arizonica*) is encountered in Stone Cabin Canyon, which drains the north side of the high Santa Ritas, on slopes toward the bottom of gulches at about 6,500 feet. Like the more shady and precipitous hanging habitats of Douglas fir, its first occurrences at this level are upon northerly slopes, and like the fir and all the other species noted, it descends farthest in the bottom of the V-shaped draws and gulches, and ascending, gradually climbs the slopes on either hand. Going higher, it presently replaces the oak brush on east and west slopes. It is the most abundant forest tree on many slopes of lesser gradient thence upward, is largely replaced by oak chaparral on the austral side of Horse Ridge, reaches quite to the summit of the high crest westward, and almost to the top of Mt. Wrightson. While at these elevations hardly producing a continuous forest, it is quite general on all sides of the higher mountains, occupies many slopes almost exclusively with *Quercus reticulata* or *Muhlenbergia gracilis*, while in moister, colder places *Pinus strobiformis* sometimes successfully disputes its ground. If the mountains were high enough, there is little question that the same concentration on southerly aspects that obtains among the oaks, would ultimately appear in the pines as well. In fact, at the same elevation in the Chiricahua Mountains the Engelmann spruce and Douglas fir replace it entirely on a number of areas on the north side of the several main summits.

The widely prevalent, low and thorny evergreen underbrush known as *Ceanothus fendleri* was first noted in small numbers, yet as a distinct constituent element, on a west slope well covered with thrifty oak brush, the deciduous Schmaltzia, and other Transition species, at an altitude not exceeding 6,000 feet, indicating a habitat comparatively mesophytic for this aspect and level. In the still more mesophytic forest ensuing it was absent, but immediately upon getting over the crest of Horse Ridge, 2,000 feet above, a cover of shrubs of this species, penetrable only with difficulty, took complete possession of the interspaces in the evergreen oak chaparral very similar to that below. On the north side opposite, the smooth, grassy floor of the Douglas fir forest, entirely devoid of the chaparral species, bore as conspicuous plants only lupine and a slender, deciduous wafer ash (*Ptelea*).

Another example is the madrone (*Arbutus arizonica*), found on the most favorable slopes of Stone Cabin Canyon at the unusually low altitude of 5,500 feet, in the middle of the Upper Sonoran. It is here a large shrub, or a small tree, but a large tree occurred at the lowest limit in a thicket in the bottom of a gulch. Again near the main crest of several gnarled individuals were noted, advancing on the open side of the forenoon sun to a height of 8,500 or 9,000 feet.

The most remarkable range of any species on this route up the Santa Rita Mountains is possessed by *Yucca schottii*. Found on the sunny southeast mountain side at a height of fully 9,000 feet, it was common and conspicuous at 8,000 in similar habitats. Like a number of other species already noted, it vanished in the Canadian forest of Douglas fir, wafer ash, walnut and lupine at the head of the canyon, only to reappear far below at the lower edge of the Transition, and to continue down to 5,500 feet into the Emory oaks of the middle Upper Sonoran. Thus it spans a vertical distance of two-thirds of a mile, and like the other interrupted species, unquestionably continues without interruption wherever a more open route is followed.

In the Chiricahua Mountains, the different species behave likewise. As elsewhere noted * *Quercus reticulata* accomplishes complete reversion within a rise of 2,000 feet. *Pinus arizonica* as already indicated, shows the same features as in the Santa Ritas. Douglas fir descends to 6,500 feet, on some steep, strictly north slopes only, but while still manifesting preference for the north sides, becomes somewhat "careless" of aspect about the highest elevations. Mexican white pine, found at the head of Chaperon Canyon at 7,500 feet on one of its steepest and shadiest north slopes, increases upward and is strongly and generally represented about the summits, on south as well as north sides. Where the high elevations fall off southerly toward head of Rucker Canyon, the three preceding species hide their lower limits in the gulches at points several hundered feet higher than elsewhere, as may be expected. The handsome white fir (*Abies concolor*), much more restricted in range, having been seen in company with *Pinus strobiformis* at the lowest station of this species above noted, seeks only the shady pockets and springy spots below, but is at home more openly on some Douglas fir slopes at higher altitudes, particularly about Long Park. Even the boreal Engelmann spruce (*Picea engelmannii*, limited in characteristically dense forests to the highest northerly slopes, descending to 9,000 feet in places, on the immediate summit of Cave Peak at 9,700 feet, the highest summit of this range, begins to emerge upon east and west sides, and associates with aspen, Nuttall willow, and *Pteridium aquilinum pubescens.* Its companion, the aspen (*Populus tremuloides*), though descending to about 8,000 feet with the white and Douglas firs in places simulating most closely its northern habitat, appears for the first time on the side of the afternoon sun on the southwestern flank of Fly Peak at an elevation of 9,200 feet. No rocky talus, often giving rise to colonies of mesophytic species out of place, is present, and the slope is compapratively smooth and open. Here is also met *Holodiscus australis*, of similar, though less pronounced habitat affinities. Though best developed about shady boreal nooks and northerly slopes at this altitude, *Salix nuttallii* is also encountered here, while on the north side of Monument Peak it descends to 8,400, and in certain gulches on the north side of the Rincon Mountains to 8,400 feet. At the latter altitudes it is limited to the aspect named.

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*Plant World, XI, 120, 1908.

In the last named mountains the reversal of aspect between altitudinal limits was found clearly repeated. During an ascent of Rincon Peak, the blue oak (*Quercus oblongifolia*) was first met at 4,000 feet, on northerly slopes of the spur flanking Rincon Creek on the south. It continued with slight interruption in its characteristic open stand on top of the spur, confined itself at length to the sunnier aspects, and disappeared at last on the most open west and southwest aspects. In ascending the Manning Trail to the northern Rincons, it is first seen hugging the northwest slopes of the gulches, marking here the first outposts of the Upper Sonoran zone at approximately 4,500 feet. About 300 feet higher it becomes general in its orchard-like disposition, and already at 5,600 to 5,700 feet the last blue crowns of this pretty oak become confined to the last open, grassy areas on slopes receiving the most sunlight. At approximately 4,500 feet *Quercus emoryi* made its first appearance in rocky gulches and north slopes in the southern Rincons, but in the chaparral belt between 6,500 and 7,000 feet its final occurrence was on steep southwest and west slopes only. Ascending the Manning Trail, which lies open to desert winds on the southwest mountain side, it first appears a little higher on the northwest side of the trail-bearing ridge, and its last representatives are seen at 7,000 feet, on a strictly southern slope. On the southern Rincons, *Quercus* *arizonica*, seen first in shaded, northerly places, soon became increasingly prevalent, was still occasionally present high up on the southwest side of Rincon Peak, but consistently absent from the steep, northwest slope taken by its two congeners next higher in range. Returning to the Manning Trail, it is first met on the shady side of a rocky projection at about 5,400 feet in ascending, and on the first sunny slope below the pine forest in descending. On the other route, *Quercus hypoleuca* first appeared on a steep northwest ascent with *Ceanothus fendleri* at a point between 6,500 and 7,000 feet, ushering in true chaparral. It is the principal constituent of large bodies of chaparral thence upward, continuing almost to the summit, but above the limit of the Arizona pine is more and more displaced by *Quercus reticulata*. It approaches the ultimate summit only on the most direct south slopes, where it is still a little taller than its more numerous neighbor last named. Again returning to the Manning Trail, it first shows itself on the left or northwest side of the ridge, and barely disappears from the austral side of the hills before the summit is reached, though replaced by the herbaceous plants of the pine forest on boreal aspects. Its companion, *Q. reticulata*, appears on this route in similar northerly and otherwise sheltered situations, displacing the other more and more on the higher slopes toward Mt. Ochoa. Given similar topographic conditions, one or both together replace the pine invariably on the most southerly aspects. The same is true at similar altitudes in the Chiricahuas and the Santa Catalinas. On the Rincon Peak ascent, the netleaf oak was not seen until reaching the shade of the pines, but above the more level pine forest it formed dense bodies of typical and almost insurmountable chaparral on the steep slopes, either loose or rocky, approaching the summit on the south as well as the northwest side. It was especially tall on the latter aspect, being here diversified by an occasional small Douglas fir and Mexican white pine. It remained the principal part of the chaparral to the ultimate summit at 8,465 feet. On the razor-edge crest dropping eastward just under the summit, however, it was absolutely confined to the dense evergreen chaparral on the open south side. The north side, partly enclosed by precipitous crags, in the complete absence of the chaparral, was possessed to the very edge by the two coniferous trees named above, deciduous white oak, woods, grasses and sub-alpine herbs.

In descending the Manning Trail, the first specimens of pinyon (*Pinus cembroides*), *Garrya wrightii*, *Yucca schottii*, *Nolina erumpens*, the first manzanita chaparral, and other characteristic species denoting the advent of semi-xerophytic conditions, appear together where the trail turns out of the Arizona pine forest down a south slope, at an altitude of little under 7,000. With these are associated, also making their first appearance, such other species as *Aristida schiedeana*, *Hedeoma drummondii*, *Oryzopsis fimbriata*, *Lycurus phleoides*, *Calliandra reticulata*, *Parosela albiflora*. Here are also the first Chihuahua pine, Arizona white oak, and the first considerable numbers of alligator juniper (*Juniperus pachyphlœa*). As we descend, all of these become more or less general, and finally, more or less completely, and many of them in company, seek seclusion on the shadiest slopes, all disappearing before the Lower Sonoran is reached, and the first giant cactus rears its head on the sun-scorched opposite side.

The phenomenon of change of aspect with altitude may also be observed in more general features of plant geography. An instance is beautifully shown in Happy Valley. Here several parallel ridges extending east and west at the same level have only open grass country, dotted here and there with a solitary oak, on the south side, while the oak woods are well developed on the north. The sharp crests of the ridges mark with equal abruptness the change from one to the other type. On the ridge which marks the northern boundary of the valley also extending east and west and some 2,000 feet higher, the same oak-woods type is now seen on the south side, while immediately on the north loom the spires of pine trees. On the opposite side of the Rincons, the scattered outposts of the pine forest, marked by *Pinus chihuahuana*, appear on the northwest side of the ridges as low as 6,500 feet. On the southerly aspects, however, the first stragglers are detected far up toward Spud Rock, some 1,200 feet higher.

The desert traveler, in following an arroyo or wash near the transition between the Lower and Upper Sonoran zones, may often find one zone developed on the bluffs on the one hand,

and the other zone on the side opposite. The bluffs facing the fiercely burning sun are usually clothed with such types as *Acacia constricta*, *A. greggii*, mesquite, other thorny shrubs, and cacti. The sides of the bluffs facing north, particularly if they are steep and well set back between other protruding bluffs, are usually clothed with perennial grasses, dotted with *Yucca*, *Nolina*, *Agave* or *Dasylirion*, and not infrequently, particularly toward the base, are found thickets of such shrubs as *Rhoeidium*, *Schmaltzia*, and *Morus celtidifolia*, true types of the Upper Sonoran. Similarly, a canyon bottom or the top of a ridge in the mountains may give us a clean-cut division between Upper Sonoran and Transition societies. The altitude for the canyon, forour region,will be near 6,000 feet and for the ridge often above, 7,000 feet. The Upper Sonoran has now reversed its position with reference to the sun. Again, about 1,500 feet higher, another ridge or canyon having the direction of a parallel will give a similar abrupt change to the Canadian zone, and the Transition has changed its position. Higher still, as for instance, on the summits of the Chiricahuas and less distinctly so on Mount Lemmon, the Canadian in turn is found to have appropriated the south sides, having yielded the cold boreal slopes to the Hudsonian.

Without multiplying instances, it may be stated that this reversion of aspect with altitude is a general truth, at least in the Southwest. From desert to mountain top, no species has been observed to behave to the contrary. The same tendency may be discerned between the heart of the Arizona desert and sea-level. The fact holds true not only for the great character species upon which our zones are based, but appears true also for those of discontinuous distribution, like *Lippia wrightii*. It may be expected to hold in similar mountainous desert regions in the northern as well as southern hemisphere, in the latter with the points of the compass reversed, It should not hold for equatorial mountains, but, except as modified by other influences, should be true for more humid regions, and increasingly true with ascending latitude, for it appears to be simply a question of the obliquity of the sun's rays, their effect probably being intensified in acting through a highly rarified desert atmosphere. The primary cause of the floral difference between two directly opposing aspects is a difference in insolation. Although precipitation and atmospheric conditions may interfere, the same primary cause is operative in change of aspect with altitude. The sun is the direct source of both heat and light, and, aside from precipitation, modifies to a large extent the moisture supply in both soil and air. A high slope receiving direct rays will in its conditions be equivalent in some measure to a low slope with oblique rays.

The following remarks, it is needless to say, are based on much more observation than is detailed above. It has been suggested that some of our species do not occupy as much ground as they are capable of doing, either within or without their geographic areas, and that the way is open for their active advancement and invasion of unoccupied areas. However well this may fit plants under cultivation and a certain class of domestic weeds, whose living conditions are made for them, it certainly can not hold true of the wild plants that lend the Southwestern desert and mountains their true physiognomy. Go where you will, the recurrence of the same kind of habitat is almost invariably accompanied by the reappearance of the same plants and plant associations. In the desert, the same soil and other features of physiography bear quite generally the same societies. In the mountains, without instrument or map, one can determine the altitude within a very few hundred feet by the species he meets on the slopes. If direction should be lost, one can quickly re-orient himself by the plants found on the various aspects. Every similar situation bears a similar coterie of species, and a very few species give any indication of movement, either forward or backward.

As seen above, many of the variations found in some species are distributed according to the different altitudes and aspects, and also to the geology and soil. Both in form and local distribution, there is constantly apparent a close fitting of the plant to the place where found. Local ranges of the various species, which are usually circumscribed areas within their geographic ranges, are exceedingly well defined, each corresponding to a certain range of habitat conditions. These conditions consist of various components, chief among which are moisture and temperature. As already indicated, in their effects upon the presence or absence, life history, form, and structure of the plant in a given habitat, these components may balance or offset each other to a certain extent. For example, the high temperature of a canyon at low altitudes appears often to be offset in the plant economy by an abundance of moisture. What all the different components are, and especially how they act, is for the physiologist to determine.

The species of widest local distribution, which are frequently also those possessing, for their size, the largest number of individuals per square mile, are usually those exhibiting the largest number and the widest range of variations. It is this versatility or comparative plasticity that must enable such a plant to achieve predominance over its fellows, and to extend or hold its range. But even to it, no considerable or rapid extension of its range appears possible, nor will it on the other hand be likely to lose its ground while the present geologic age and climatic conditions endure.

Tucson, Arizona.

BOOKS AND CURRENT LITERATURE.

PLANT-ANIMALS.—The little book under consideration* brings to the layman in popular form the contents of several scientific papers on two worms belonging to the genus *Convoluta.* It consists of two parts, one devoted to the structure, activities and general habits of these animals, the other to the relation between them and the symbiotic algae which they contain.

Among the most interesting characteristics in the behavior of the *Convoluta* is the periodic activity they have acquired in correspondence with that of the tides. This is especially marked in the green species *C. roscoffensis* which is found only on certain sandy beaches of Normandy and Brittany just below the high-water mark of the slackest neap tide. When the tide is out they are found on the surface forming a thin green film, but as soon as it comes in they crawl into the sand and disappear from view. Twice a day then these animals, in response to the rythmic movement of the tides, alternately expose themselves to the light on the surface of the sand and bury themselves in it. However when the tide is out at night the animals do not come to the surface unless there is strong moonlight. This occurs every other week, and it is at this time that the animals deposit their eggs, another periodic phenomenon controlled by the movements of the tides.

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*Plant-Animals:—A Study in Symbiosis, by F. Keeble, 163 pp. Cambridge, 1910.

In the laboratory, although not subjected to the action of the tides, the animals keep up their periodic movements for nearly a week if exposed to light, but in total darkness only a day or less. These movements the author holds are due to the tonic effect of light on the response to gravity. Light he maintains induces certain chemical changes which make the animals positive to gravity and darkness produces the opposite effect. However, the fact that periodic movements continue in darkness, even if for but a short time, appears to militate directly against this theory. The periodic movements must depend in some way upon internal periodic processes which in some instances continue in the absence of immediate external stimuli for considerable periods of time, sixty days and more as recently discovered by Menke.

There are according to Keeble four different methods of response to light—tropoisms, taxes, back-ground reactions and phototonic responses. The assumption, however, that the back-ground reactions are essentially different from the others mentioned does not appear to be well founded. Taxes are defined as movements in a definite direction and tropisms as "purposeful curvatures,"—another addition to the multifarious definitions already devoted to this term.

Keeble concludes that the reactions are highly adaptive. After opposing the idea that reflexes are "unalterable and inevitable" he says p. 43: "They are but servants, and tropistic reflexes serve the master-organisms, to draw it this way or that according as it is well that, this or that route be taken." And again, p. 44: "The organism takes the habit, for example, of relying implicitly on the stimuli of light and gravity. By responding to these stimuli, it finds its proper place with such certainty that other modes of response to other stimuli are ignored habitually."

By means of isolation and sterilization the author was able to prove that the green cells in the *Convoluta* originate from a free swimming alga, one of the clamydomonads, which infects the larvae soon after hatching. He raised colorless larvae but found that they went to pieces long before maturity, indicating that these animals are dependent upon the algae for essentials in their food supply and for the elimination of nitrogenous wastes, the excretory system being entirely lacking.

The algae when free have a cell wall, four flagellae, a nucleus, a pyrenoid, an eye-spot and several chloroplasts. All of these except the chloroplasts degenerate and disappear after existence in the larvae for a few generations. This the author thinks lends support to the suggestion of Schimper and Lankaster that the chloroplasts in the higher plants originated by the degeneration of symbiotic algae.

The book as a whole is very interesting and well worth while, but I cannot forbear entering a protest against expressions such as the following, which, in the mind of the present writer are neither popular nor scientific and serve only, especially in the layman's mind, to mystify what actually occurs in the responses of these organisms. "They phototrope themselves to the light," p. 64; "It takes the hint and photrotropes," p. 70; "Vibrations . . . . . troping," p. 67.—S. O. MAST.

VEGETATION IN THE ALPS.—Rübel has published * the results of an extended study of the climate and vegetation of the Bernina Valley and its adjacent peaks, in the upper Engadine region of the Alps. The author lived for over one year at the Hospice of Bernina and carried on personally the principal part of his instrumentation, at the same time that he used for comparison all reliable climatological records for his region. The Hospice of Bernina is at an altitude of 7,578 feet; (2,309 m.)

*Rübel, E., Pflanzengeographische Monographie des Berninagebietes. Botan. Jahrb., 47 1, pp. 1-296; 36 plates and map; 1911.

the entire area studied reaches from 5,610 feet (1709 m.) at Samaden to 13,303 feet (4055 m.) at the summit of Bernina Peak, embracing the drainages of the Bernina and the Roseg rivers. The climatological data presented by Kübel include the various phases of temperature conditions; readings of black bulb theremometer *in vacuo*; percentage of cloudiness; force and direction of wind; evaporation during the summer months; humidity; precipitation; soil temperature and light intenstiy. All of these data are presented in such a manner as to show the seasonal march in different seasons. Many comparative data are given from St. Moritz, Pontresina and Vienna. The evaporation readings are from the Wild instrument, protected from insolation, and largely from wind action. The light intensity data were secured by the Wiesner method. At the Hospice of Bernina the temperature extremes are —9° Fahr. (—23° C.) and 75° Fahr. (24° C.),frost being liable to occur in every month of the year;the precipitation is 63 inches (1,600mm.), higher than at any of the lower localities in the vicinity; the evaporation varied from a monthly minimum of 1.4 inches(36mm.) in August, 1905, to a maximum of 4.1 inches (104mm.) in August, 1906, being higher than at Vienna in the former and lower in the latter summer; the highest mid-day light intensity was to that for Vienna as 6 : 5, the lowest to Vienna as 12 : 1. The vegetation is described under the following principal groups of formations: the coniferous forests of larch and Scot's pine, the tall scrub of pines and alders, the low scrub of *Vaccinium*, *Arctostaphylos*, *Juniperus* and *Erica*; the moist and dry meadows; the "hochmoor" and "flachmoor"; the aquatic vegetation and that of the rocks, sand and gravel. The description of the vegetation is most thoroughgoing and embraces detailed facts as to the occurrence of every plant association and the vertical limits of the species involved. The numerous illustrations and the very detailed map of the distribution of the various formations aid in giving a clear portrayal of the botanical aspects of the higher Alps.

An attempt to determine the entire constellation of climatic conditions for a region, and to make also an exact study of the occurence and distribution of its plant associations and individual species, is an undertaking of no mean magnitude, and Rübel has accomplished these ends with conspicuous success. An attempt to draw from these two sets of facts some inferences regarding the relative weight of the several factors, and the critical points in their operation, as related to the controlling of plant occurence and the distribution of the associations involved, is a still more difficult undertaking. It can only be regretted, however, that Rübel has not made this additional step. He has given an admirable presentation of two great sets of facts without making any attempt whatever, in the present paper, to correlate them.—F. S.

NOTES AND COMMENT.

The entrance of any person into science in a serious manner is usually connected with the work carried out during his candidacy for the doctor's degree, and the details of the 437 doctorates granted by American Universities in 1911, may be taken to indicate with considerable probability the character of the life-work of the botanists included.

Twenty theses are credited to departments of botanical science, but as nine others in agriculture and bacteriology are so fundamentally botanical, they are included in the following list extracted from the original article. *

Charles Orval Appleman: "Some Observations on Catalase." (Chicago).

Grace Miriam Charles: "The Aantomy of the Sporeling of *Marattia alata.*" (Chicago).

William Skinner Cooper: "The Climax Forest of Isle Royale, Lake Superior." (Chicago).

Thomas Haigh Glenn: "Variation and Carbohydrate of Bachilli of the Proteus Group." (Chicago).

Mary Sophia Young: "Morphology of the Podocarpineae." (Chicago).

Le Roy Abrams: "A Phyto-geographical and Taxonomic Study of th Southern California Trees and Shrubs." (Columbia).

Ralph Curtiss Benedict: "The Genera of the Fern Tribe Vittarieae." (Columbia).

Frank Dunn Kern: "A Biologic and Taxonomic Study of the Genus *Gmynosporangium.*" (Columbia).

Alvin Carey Beal: "A Study of the Genus *Lathyrus.*" (Cornell).

George John Bouyoucos: "Transpiration of Wheat Seedlings as affected by Soils, by Solutions of Different Densities, and by Various Chemical Compounds.'' (Cornell).

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*Doctorates conferred by American Universities. Science. 34: 193. 1911.

Harold Joel Conn;A Study of Seasonal Variation among the Bacteria in Two Soil Plats of Unequal Fertility.'' (Cornell).

Hing Kwai Fung: ''An Ecological Study of the American Cotton Plant with Incidental Reference to its possible Adaptability in China.'' (Cornell).

Lewis Knudson: ''The Relation of *Aspergillus niger* and *Penicillium* sp. to Tannic Acid Fermentation.'' (Cornell).

John Pogue Stewart: ''Factors Influencing Yield, Color, Size, and Growth in Apples.'' Cornell).

Frederick Adolph Wolf: ''The Life History and Development of a some Fungi.'' Cornell).

Robert Fiske Griggs:''The Development and Cytology of *Rhodochytrium.*'' (Harvard).

Alban Stewart: ''A Botanical Survey of the Galapagos Islands.'' (Harvard).

William Ralph Jones: ''The Development of the Vascular Structure of *Dianthera Americana* L.'' (Johns Hopkins).

Harlan Harvey York: ''The Origin and Development of the Embryo-sac and Embryo of *Dendropthera opuntiodes* (L) Eich. and *D. gracile* Eich.'' (Johns Hopkins.)

Neil Everett Stevens:''The Meitoic Phase in Heterostylous Plants.'' (Yale).

Frederick McAllister: ''The Cytology of Convallariaceae.'' (Wisconsin).

William Alderman Matheny: ''Biology of *Sclerotinia fructigena* and *Sclerotinia cinera.*'' (Clark).

Walter Byron Gernert: ''Unit Characters in Corn and their Behavior in Transmission.'' (Illinois).

Louis John Gillespie:''The Gas Metabolism of the Colon and Typhoid Bacilli.'' (Brown.)

Eugene Clarence Howe: ''A Biometric Investigation of certian Non-spore-forming Intestinal Bacilli.'' (Mass. Inst. Tech.)

Leonard Dixon Haigh: ''A Study of the Variations in Chemical Composition of the Timothy and Wheat Plants during Growth and Ripening.'' (Missouri.)

Caroline Rumbold: ''The effect of the acidity and Alkalinity of the Substratum on the Growth of Wood destroying and Wood-staining Fungi, with a discussion of the Systemiate Relation of *Ceratostomella* and *Graphium.*'' (Washington).

Otto E. Jennings: ''The Mosses of Western Pennsylvania.'' (Pittsburg.)

Seven of the twenty are almost purely taxonomic, nine are of a definite morphological character, two are ecological and two physiological. Very few botanists could be found who might assert that these figures represent the relative importance of the subdivisions of the subject, and the casual examination of the contents of a recent volume of the Botanisches Centralblatt would make is obvious to the most prejudiced reader that the actual present activity in botany is far different from that indicated from the analysis of this thesis list. It may be profitable therefore, to inquire into the conditions responsible for this botanical misfit. This will lead at once to a consideration of the things which determine the direction of the activities of a young botanist. The factors in the order of their actual force appear to be, first, the specialization of the instructor, second, the equipment, facilities and material available, and third, the predilections of the student. The training of the incumbents of the principal chairs and most important teaching positions in America has been one in which morphology predominated and it is readily apparent that equipment for work in anatomy, embryology, cytology and taxonomy are much more easily procurable than the facilities for experimental work in physiology. The content of most problems in taxonomy and morphology is snugly definable and sharply limited. Both instructor and student are inclined to follow the line of least resistance in selecting work, and with more regard to the possibilities of mechanical completion than to the elemental importance of the questions to be answered. The attainment of a formal stage in an academic career, especially for a beginner, does not suggest plans for experimental research in plant physics, chemics, or morphogenics, consequently candidates are frequently permitted to spend two or three years upon topics, which may yield little beyond disclpline, and a moiety of assortable information. Neither this training nor the perspective required with it,however, fits the young botanist for an appreciation of the direction of the movement of botanical science at the present time. Lacking this comprehension, he may not be expected to render very efficient service in presenting the essentials of the subject in teaching, to contribute materially to its development or to aid in the articulation of its principles with those of nearly related sciences.

That the unhampered choice of a normal proportion of candidates would lead them into experimental work is well attested by information reaching this journal, and that the beginner with a training in exact methods of experimentation would find opportunities for work equal to those in any phase of botany is beyond question. In addition to the tasks of instruction and development of the principles underlying physiological science, there also may fall to him the task of applying botanical information in genetics, horticulture, agriculture, soil physics, etc. That the Adams Fund for agricultural research in the experiment stations has attained only a fraction of its possible usefulness due directly to a lack of skilled experimenters to take up its problems is a matter of common knowledge.

By the very nature of the problems the physiologist must be prepared for a wider range of original activity than is the worker in any other phase of the subject. He must hold himself in readiness to go far afield; to build cantilever bridges the farther end of which may rest well within the domain of physics and chemistry. It was by such methods that DeVries established the conception of isotonic coefficients, and Pfeffer made his experiments in osmosis, both discoveries being no less vital to physics and chemistry than to botany. The acknowledged desirability of the meeting and conjunction of the separate sciences (if there are such things) is one which may be well illusfrated by the fact that the candidate with a wisely chosen subject may find in his minors, methods and information essential to the development of his main theme. The results of a research of this kind will be likely to interest a wide audience. It is thus to be seen that while research in physiology may make heavy drafts upon the time and energy of the young investigator, yet his reward is that of a wide horizon, and of countless opportunities for profitable cooperation and contribution to the advance of biological science.

The nine titles of interest to botanical science in addition to the tentwy credited to the departments of botany are all of a physiolgicaol character. Two of the twenty ar physiological making it appear that the student who desires to make a physiological study of plants must usually seek his guidance and facilities elsewhere than in the existing departments of botany. It is gratifying to note that this abnormal condition is becoming recognized and while but two universities have rezently made provision for additional facilities for work in plant physiology, a half dozen others are considering prospects for i samilar development. Meanwhile the beginner, like those now engaged on the subject in America, must get his experience by hook and crook in the great majority of institutions.—D. T. M.

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During my residence in Miami, Florida, in charge of the Subtropical Laboratory and Garden, I observed frequently the common Rubiaceous shrubs of the hammocks and was much impressed with their similiarity to the coffee plants which were growing at the Subtropical Garden. This similiarity was so great that I collected a quantity of the berries of the commonsest of these plants, *Psychotria undata*, separated the seeds from the pulp and made the following experiment. The seeds were heated in an open test tube over a Bunsen burner, stirring them constantly in order that the browning might be carried on evenly. During this process a delightful aroma as of coffee was given off. On the completion of the browning process the seeds were ground up in a mortar and put into boiling water and kept at the boiling point for some time (perhaps two or three minutes). The odor and color of the resulting solution were those of weak coffee. Unfortunately my experience in coffee making was so slight that the amount of water used in this experiment was far more than should have been used had it really been coffee that I was using. In spite, however, of its diluiton several people who were given the opportunity to taste the concoction all agreed with the writer that the taste was that of weak coffee.

The writer's permanent removal from Florida soon after prevented the matter being followed up further, as it should be. Analyses should be made of the seeds to determne whether we have in the country a real coffee plant even though it belongs to a closely allied genus instead of to the true *Coffea*. *—ERNEST A. BESSEY.

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*Read before the Michigan Academy of Sciences at the meeting April, 1911.

Volume 14 Number 11

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

NOVEMBER, 1911

CERTAIN PHASES OF THE BEHAVIOR OF THE STIGMA-LIPS IN DIPLACUS GLUTINOSUS NUTT.

FRANCIS E. LLOYD

The Bush Monkey-Flower, *Diplacus*, the monotype of its genus, possesses, in common with *Mimulus*, *Torenia* and *Martynia* a sensitive two-lipped stigma. Responding to the temptation of an abundance of material growing at Carmel, California, near the Botanical Laboratory of the Carnegie Institution of Washington,during the summer of 1911, I attended somewhat closely to certain features of the behavior of the stigma lobes, with the result that there emerged conclusions at some variance with those stated in current text-books, and indeed with those of previous investigators.

Correns * in his study of the dependence of irritable phenomena upon the presence of free oxygen included in an extensive series of forms examined by him, the movements shown by the stigma lips of *Mimulus moschatus* and *M. luteus*. He observed that the lips close under reduced atmospheric pressure, but showed that this is due to the reduction of the oxygen tension, and not to any physical effect of the reduced pressure. If the period of exposure is too long, the lips remain closed, but if not, they open again and respond to mechanical stimuli as before. A similar behavior was observed on exposure to ammonia gas. Correns regards the change in the amount of oxygen as the stimulus, since its effect is analagous to that due to variation in the amount of light, as in the case of *Mimosa*. Ammonia, however, he believes to be a chemical stimulant.

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*Correns, C. Ueber die Abhängigkeit der Reizerscheinungen höherer Pflanzen von der Gegenwart freien Sauerstoffes. Flora 75:87-151 1892.

The first critical study of the question of transmission of the stimulus in these plants was made by Oliver [†], the species receiving attention being *Mimulus cardinalis*, *M. luteus*, *Martynia lutea* and *M. proboscidia*. Oliver's purpose was to determine the path of transmission of the stimulus from one stigma-lip to the other, since, according to him, this occurs in all these species except in *Mimulus luteus*, in which the stimulus is not so transmitted. This I am able to confirm.

By a nice method of excising a portion of the vascular tissue from one lip, it was proved by Oliver that there was no hindrance to the transfer of the stimulus to the other, thereby showing that, in these forms, the path of transmission lies in the parenchyma. Oliver believed that this is made possible by the presence of protoplasmic continuity, a conclusion which seems reasonable, but not yet demonstrated to be true. The immediate cause of the movement of the stigma lip this author finds in the movements of water into the intercellular spaces, the presence of which has been previously denied by Kabsch [‡] and by E. Heckel [*] and affirmed by Mitchell[*] with whom Oliver properly agreed. Oliver's description of the structure of the stigma-lip appears to be applicable to *Diplacus* except for a slight and not important omission, namely that the epidermis of the outer face is relatively quite thick, and has in the absence of turgor in the motile tissue a considerable power of recovery when bent away from the plane of the style. [*] [†]

Burck [*] studying *Torenia fournieri* and *Mimulus luteus*. found that the presence of appropriate pollen causes the stigma to remain closed, the closure following mechanical stimulus. This work will be referred to more specifically beyond.

THE NATURE OF THE STIMULUS

Under normal conditions the entrance of a large enough insect into the mouth of the corolla causes the displacement of the lower lip. This then moves forward, straightening and finally curving upwards to oppose closely the upper lip (Fig. 1). After an interval of about half an hour the lower lip resumes its former position, *whether pollen has been received on the stigmatic surface or not.*

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[*] Oliver, F. W. Ueber Fortleitung des Reizes bei reizbaren Narben. Ber. d. D. Bot. Gesellsch. 5: 162-169. 1887.

[*] Kabsch W. Uber die Einwirkung der gase usw. Bot. Zeitung, 1862, p. 341. (through Correns l. c.)

[*] [*] Du mouvement vegetal, Paris, 1875, p. 89 (through Oliver).

[†] [†] Archives des sc. phys. et nat. de Geneve, 15 Feb. 1875 (through Oliver).

[†] On the importance of similar mechanical tissue, but of greater extent, in the motile stamens of *Berberis* and *Centaurea* see Juel, H O., Einige Beobachtungen an reizbaren Staubfaden. Bot Stud. tillagn, F. R. Kjellman, 1906.

[*] [†] Burck, W. On the irritable stigmas of *Torenia Fournieri* and *Mimulus luteus* and on means to prevent the germination of foreign pollen on the stigma. Proc. Kon. Akad. v. Wet. te Amst. Sept. 20, 1901. (Ref. in Bot. Central) bl. 89 (No. 23) 645. 1902.

Mechanical Displacement the Normal Stimulus.—Merely touching * the papillate stigmatic surface, or bending the papillae does not constitute a stimulus. This is shown by the fact that stroking the surfaces with a delicate rod (a broken style) without causing any displacement of the lip as a whole produces no response. The experiment was repeated a number of times, a dozen or more strokes being given in succession. It is hardly possible that the operation could be done without actually displacing the papillae in a direction at right angles to their longer axes, from which it would appear that the epidermis of the inner face of the stigma is either not sensitive, or, if sensitive, is incapable of effecting a visible response to either touch alone or later displacement of the papillae. Further, the stimulus, if effective in any degree, does not pass beyond the epidermis into the tissue below. In this connection it may be noted that the shape of the epidermal cells is such that the mechanical effect of turgor changes will be minimized, namely, by the free walls of the papillae.

Backward Displacement.—By this is meant displacement of the lip by pressure on its stigmatic surface. The pressure may be applied so as to move the whole lip or to bend it within a definite zone. The entrance of an insect has the effect of bending the lower lip transversely throughout its whole extent.

In order to cause response this displacement must be sufficiently rapid. I have been able, by steady pressure from the finger tips, to displace the lower lip (this being more convenient to work with than the upper) through a wide angle quite slowly, allowing equally slow recovery, without response. The same gentle displacement through a small angle at a temperature of about 70°Fahr. repeated five times at two second intervals, produced, on several trials, no response. If, however, the displace ment is produced by a sharp thrust a definite, rapid response follows.

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*J. R. Green (Vegetable Physiology, p. 384) says "The stigma of Mimulus —will, if either lobe is touched with a fine point, close—."

If such a thrust is applied so as to bend the lip chiefly in a transverse zone near the base, as indicated in *a*, Figures 2 and 3, the consequent bending will be confined to that zone, and the curvature of the lip, seen in profile, will be represented in Figure 4. If, however, the thrust is applied to the apex of the lip so as to bend it in a transverse zone near the apex, (Fig. 2 *b*) the curvature is similarly confined to this zone. The resulting response is as shown in Figure 5. Either lateral edge of the lip behaves similarly by appropriately confining the thrust, e. g., to the zone *c*, Figure 2. * A complete curvature of the lower lip so as to oppose itself against the upper (Figure 1) results only from such displacement as directly affects all the cells of the motile parenchyma. The above is equally true of the upper lip also, but there is no transmission of stimulus from one to another, *Diplacus* agreeing in this regard with *Mimulus luteus* (Oliver *l, c*).

Further, if the pressure is not applied symetrically with reference to the median plane, by applying pressure with a very slender, lead-tipped glass rod at, say, a point indicated by *d*, Figure 2, the movement is greater on the side receiving the greater pressure. The one lip thus takes an oblique position with reference to the other, (Figure 2, *d*.).

The most obvious inference to be drawn is, that the stimulus is not only not transmitted from one lip to the other, but that it is not transmitted at all. The alternate inference, that it is transmitted weakly for a short distance only, has logical value as a possibility and is, indeed, suggested by the fact that the cognate forms which have been mentioned fall, according to the results of the workers above mentioned,into a series of decreasing sensitiveness with *Diplacus* the lowest member.

Forward displacement, that is, pressure on the outer face of the stigma-lip (Figure 3, *c*). Because of the curling back of the edges of the lip, it is important to avoid bending them in applying pressure to the back. The bead-tipped glass rod was successfully used for the purpose. The following experiments are typical.

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*I have found this account true of *Mimulus luteus*.

(a) A single forward thrust against the middle of both upper and lower lip produced no response, nor was there when the stimulus was repeated after 30 seconds. The lip closed after a single backward thrust.

(b) Steady pressure for 20 seconds repeated after 20 seconds was followed by no response. If the pressure was continued steadily for one minute, there was displayed a tendency of the lip to remain in the displaced position, though repeated trials produced inconstant results. In all cases, a single backward thrust caused closing.

(c) Five thrusts repeated at intervals of one second, no response. Ten thrusts with similar intervals caused a displacement from the original position, but no active closing movement. Normal stimulus caused the usual response

The forward thrust causes a compression of the irritable cells, while the backward thrust, which alone is effective in causing response, stretches the tissues.

The displacement resulting from the former is, I believe, purely passive. It seems then, that the stimulus which causes closing is a sufficiently vigorous stretching of the motile tissues consequent a backward thrust. Brown and Sharp * found that the closing response in *Dionaea* follows the compression of certain cells at the bases of the sensitive hairs by the bending of these, but that release from the bent position does not constitute a stimulus. In both *Dionaea* and *Diplacus*, therefore, a mere shock appears to be insufficient since the factor of direction enters in. In order to harmonize my own conclusion, that the sensitive cells must be compressed, we may say that the plasmatic membrane must be stretched. It is probable that, if a turgid cell is distorted by pressure applied unequally (as the basal cells of a trichome such as that in *Dionaea* would be by flexure) a portion of the plasmatic membrane would be stretched, unless free to glide on the inner surface of the cell wall, a condition which probably does not obtain. Indeed, Haberlandt † showed that the sensitive cells of the convex side of the zone of bending in the *Dionaea* hair lengthened 21 percent of the original dimensions. On the other hand the bending back of the stigma-lip of *Diplacus* may have the

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*Brown, W. H., and Sharp, L. W. The closing Response in *Dionaea*. Bot Gaz 49: 290 302 April, 1910.

†Physiologische Pflanzenanatomie, 4th Ed. p. 481.

effect of compressing those cells nearer its outer surface in the manner, but not to the extent, that the basal cells on the concave side of the hair of *Dionaea* are by flexure of it. Indeed this may be said to be true of all the cells, in reduced degree, approaching the stigmatic surface, but we do not therefor remove the difficulty of explaining the effectiveness of stimulus in one direction and not in another. It appears more satisfactory at the present moment to regard the local stretching of the sensitive cells as the critical condition which calls out a response.

THE EFFECT OF POLLEN

In the third English edition of the Bonn text-book (p. 296) the statement is made that "the stigmas of *Mimulus* and *Torenia* after closing on mechanical stimulus open again shortly unless active pollen has been deposited, when they remain in a closed position." This is evidently based on the work of Burck, (*l. c.*) of which a somewhat more specific account is given by Jost *.

Burck, working with the above mentioned forms, came to results of very great interest in this connection. In *Torenia*, the stigma-lips close on pollination only after mechanical stimulus and remain closed only if they have received pollen from the two long stamens. If that from the shorter stamens, or from other genera is used, the lips reopen. In *Mimulus* pollen from any of its stamens ensures a closed condition. Burck found, however, that in *Torenia* if the pollen from the shorter stamens be dried, it becomes equally effective with that from the longer ones, or that if from the latter be first moistened, it becomes non-effective. The conclusion drawn by Burck is that the effect of the pollen is to withdraw water from the stigma cells, thus reducing their turgor and causing closure. † The movement of the stigma produced by the action of pollen is therefore not to be regarded as an expression of irritability, any more than the closure of the lips if effected by dry heat, as e. g., when a hot glass rod be held near them. Under such treatment, one can easily be assured that the closure is due to withering..

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*Jost Lectures on Plant Physiology, p. 520.

*In the review, to which I alone have access, (Bot. Centralbl. 89: 645. 1902) the word "Narbenschleim" is used. I do not find that a mucilage is present on the stigma in *Diplacus* or ***Mimulus***, and I believe that this word is unfortunate.

Without knowing of Burck's work, at the time,I was led to identical conclusions with regard to *Diplacus*. An examination of the naturally pollinated flowers shows that, especially in the earlier part of the day, there are many stigmas which, in spite of the presence of pollen, are not closed. Towards the close of the day many will be found closed and in practically all cases in which pollen is present the lips will be more or less curved. Further, pollinated stigmas display a withered aspect, and are characterized by an opacity absent from unpollinated stigmas. It is important to remark here that the closure due to the presence of pollen is not such as to closely approximate the stigma lips, and the vigorous curvature seen after mechanical response is absent. These observations led me to investigate the matter experimentally. It was found that, unpollinated, the stigma persists (in the laboratory in the climate of Carmel, Cal.) for ten or twelve days. retaining its ability to respond to mechanical stimuli during that period. Pollinated stigmas, however, do not close at once, unless pollination is accompanied by mechanical stimulus, in which event they reopen in a short time. In the absence of mechanical stimulus the stigma-lips either approach each other or each may display bendings in various directions, but *only after the lapse of several hours*, the same occuring, of course, when the pollinated stigmas reopen after mechanical stimulus. They wither completely in three or four days after pollination. The following experiments are typical. Four fresh stigmas were pollinated by placing a mass of pollen across the throat (Figure 6, *a*). They were stimulated mechanically, but the lips reopened. All four closed later. In two cases some curvature was noted in two hours and twenty minutes, in an upper lip, with which there was more pollen in contact than with the lower, it being difficult to place it in precisely the desired position. In another hour the change in position was still more marked, and was visible in all four cases. On the following morning, 24 hours after pollination, the lips were closed together at their bases, while the apices were curled away from each other., in which position (Figure 7) substantially, they remained until withering ensued three days later.

Again, a mass of pollen was placed near the apex of the lower lip, either transversely or obliquely (Figure 6, *b*). In nearly every instance in twenty-four hours there was a marked curvature in the tissue beneath the pollen (Figure 8), but not elsewhere, the lips remaining distinctly open except when withering began. In a few exceptional cases, the failure to curve may be due to the condition or character of the pollen, though I found no evidence of differences such as are observed by Burck in *Torenia* but not in *Mimulus* with which latter *Diplacus* has agreement therefor in this regard.

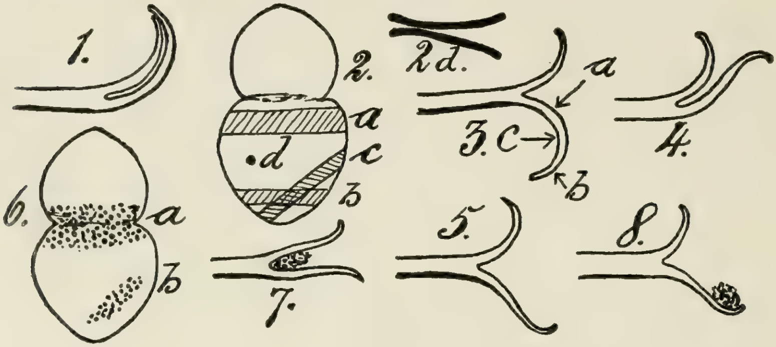

Fig. 1.

The conclusion appears therefore to be justified that the curvatures observed in the stigma-lips after the application of pollen are due entirely to the withdrawal of water from the underlying tissues, either before or during the germination of the pollen, but between these I have made no effort to decide. The potent factor in bringing the lips into their final position is, I believe, the mechanical quality of the collenchyma-like outer epidermis. My observations therefore substantiate the conclusions of Burck on *Mimulus*, except that in *Diplacus* the stigma lips open after pollination and close only after the lapse of some time, beginning in about three hours. An inquiry into the character of the pollen in these plants and into its behavior toward the stigma might very well elucidate this difference.

Heat. In order to avoid the drastic effect of dry heat, which causes withering, I used a tubulatured bell jar standing in a vessel of water to which heat was applied from below. A thermometer was introduced from above, the bulb being placed near the stigma of a flower standing in water in a vial. The corolla was removed sufficiently to expose the stigmas. Other experiments were done as indicated below.

If an open stigma is placed carefully in hot (nearly boiling) water the lips close on being killed. The same is true if the lips are held with their stigmatic faces near the surface of the hot water. When killed the tissues become opaque and yellowish in color. This closure is however preceded by a slight curling back of the lips, a movement which is probably caused by the expansion of the water in the cells just previous to its escape through the protoplasm. There appears to be no closing response to heat below the thermal death point. This was indicated in the following manner. Three stigmas, attached to the flowers, from which for convenience the upper part of the corollas had been removed, were held near a hot water surface, until the slight curling back was noticed. Two of these were killed by the exposure. The third survived, remaining open, in which position it was found the following morning. The edges of the lips had been killed however, and were withered.

The thermal death point was determined by exposure of the preparation to heat in the apparatus above described. A series of trials showed that the point lies very near to 58 degrees C. Thus an exposure for one minute to temperatures beginning with 58.5, falling to 57.5 and rising to 58.3 resulted in killing the stigmas but not the limb of the corolla,which had not been removed. Similar exposure with a range of temperatures of 59, falling to 58 and rising to 58.3 killed both the stigmas and corolla. One minute at 57, or a small fraction of a degree above and below did not kill. At the conclusion of the trials, the removal of the bell jar caused air-currents which were sufficient to cause in some cases the closing of the lips. That this was due to the mechanical disturbance and not the heat was shown by the result that, with very careful manipulation, so as to avoid an inrush of air, closure did not ensue. Thus, after a four minute exposure to 45 to 41 degrees and to 44 to 43 degrees, there was no response, nor after a one minute exposure to 48 to 47 degrees, when removal of the bell-jar was carefully accomplished. In one instance however, the evidence was not unequivocal, and there was observed some straightening of the lip, even before the removal of the bell-jar after one minute exposure to 50 to 51 degrees. The positive evidence obtained appears however to point to another explanation rather than to a true response.

The behavior toward alcohol and its vapor is analogous to that toward heat. When gently placed in nearly boiling absolute alcohol, the lips close instantly. In cold absolute alcohol closure occurs more slowly, beginning in 20 seconds and being completed in about 50 to 60 seconds. In cold alcohol, however, there is a slight backward curling previous to closure which may perhaps be referred to the shrinkage of the thick epidermis of the outer surface of the lip. The closing movement is of the same character whether induced by heat or alcohol, and ends when the lips have straightened.

Exposure to alcohol vapor under a glass for 28 minutes caused closure from which there was no recovery, the tissues being evidently dead, as three hours later they had quite shrivelled. There was no movement after 15 minutes exposure (approximately the maximum non-lethal dosage) but the lips closed on being stimulated mechanically. They subsequently opened, showing that no permanent deleterious effect of the alcohol was had. Alcohol, therefore, unlike ammonia gas (according to Correns) does not act as a stimulant but, like hydrochloric acid vapor, (Correns) and heat causes closure only by killing. It seems probable that anaesthetization by alcohol cannot be accomplished without injury.

CONCLUSIONS

The closing response of the stigma-lobes in *Diplacus* is effected by mechanical displacement , only if of sufficient rapidity and when applied against the stigmatic surface. When the stimulus is applied against the outer, non-papillate face of the lip it is non-effective. The case is thus analogous to that of the sensitive trichomes in *Dionaea* (Brown and Sharp, *l. c.*).

If mechanical stimulus is applied so as to bend only the cells within a particular zone of the stigma-lip, the response, consisting of curvature, is confined to the stimulated zone. There appears therefore no evidence that the stimulus is transmitted either from one lip to the other (as occurs according to Oliver, *l. c.*, in *Martynia* and in *Mimulus cardinalis*, but not in *Mimulus luteus*) or within the sensitive areas of either lip. That there is a slow transmission if possible, but such has not been observed in the course of the work. *Mimulus lateus* appears to me to be in the same case.

There appears to be no cumulative effect of mechanical stimuli of slight amount, each ineffective in itself.

Mechanical stimulation of the papillae of the stigmatic surface sufficient to bend these, but not the lip, is non-effective. "Touch" is not a stimulus and the stigmatic papillae are not sense organs.

The presence of pollen does not prevent a reopening of the stigma-lips, when these are closed at the time of pollination by mechanical stimulus. Whether so closed or not, the pollen causes closure beginning in about three or four hours, by the withdrawal of water from the underlying tissues. According to the position of the pollen this closure may be complete and involve both the lips, or partial, consisting of more or less pronounced curvatures in one or the other lip. This conclusion is in general agreement with that of Burck cited above, with whose observations on the effect of pollen in preventing the reopening of the stigma-lips my own on *Diplacus* are in disagreement. The closure due to pollen is not an irritable response,but is analogous to that induced by heat or alcohol and its vapor, in that it is accompanied by partial or entire disorganization of the tissues. The position of the stigma-lips, under such conditions, is to be referred to the physical properties of the thick outer wall of the epidermis of their outer faces, and not to turgor differences within the motile tissues.

A comparison of the conditions in *Dionaea* and in *Diplacus*, suggests the view that mechanical stimulus is made effective through a stretching of the sensitive cells, either local or involving the entire cell.

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THE HAMMOCKS AND EVERGLADES OF SOUTHERN FLORIDA *

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To the botanist visiting southern Florida for the first time the objects of greatest botanical interest are usually the hammocks and the Everglades, although the mangrove swamps, the tropical strand formation and the marine algæ will not lack in interest.

Let me at once dispel any notion that may have been given by my use of the word hammock that the visiting botanist will take his ease in one of those net-like contrivances so popular in the summer time on moonlight nights. As used in Florida the word hammock means a dense wood of broad-leaved trees, usually Dicotyledonous but sometimes of palmettoes, in marked contrast to the open pine woods which form the greater part of the forest covering of Florida.

In order to understand just what a hammock is it will be well first to describe the pine woods in which these hammocks are set, as it were,as islands. In Southern Florida,especially in the vicinity of Miami, where the observations of the writer were made, the species of pine concerned is *Pinus caribaea*,the Cuban or slash pine. Trees of this species may attain a height of over 30 meters and a diameter of a meter, although this is larger than the majority of trees of this species. They stand rather distantly from one another, frequently being 6 to 10 or more meters apart, thus forming a very open forest. The tops are rather small and do not give much shade, so that these open pine forests are bright and sunny and have few of the characteristics of the dense coniferous forests of the North. It is frequently possible to see objects at a distance of 800 or more meters in such a forest, so scattered are the trees. Among these pines grow dwarf palmettoes and other palms with prostrate or underground stems, as well as *Zamia* and various other low plants, Typically there is no dense shrubby undergrowth in these pine woods but only scattered small shrubs and herbaceous plants.

The hammocks form the greatest possible contrast to the pine woods in which they are generally found. They may be of but a fraction of a hectare or so in area or may contain up to several square kilometers. Ordinarily, however, their area is from two to five hectares. Instead of the open growth of the pines they are dense jungles of large and small trees, shrubs, vines and herbaceous plants, frequently forming an almost impenetrable tangle, through which progress is at best slow and difficult. In many places it is impossible to see more than three to five meters in any direction, even upwards. To be sure it is only in the densest hammocks of Southern Florida where no fires or other destructive influences have thinned them out that such thick growth can be found. So dense is the shade in some of these hammocks that at noon on a bright day the light is a sort of dim twilight, while on a cloudy day the darkness is very marked. As a consequence of this dense growth the air within the hammock is moist, the wind being almost entirely checked, while the shade reduces the drying out to a great extent also. As a further indication of the great humidity of the air within the hammocks is the presence of epiphytes of all descriptions, ferns, orchids, bromeliads, liverworts, etc.

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*Read before the Michigan Academy of Sciences, April, 1911.

The trees making up the arborescent flora of these hammocks are entirely different from those of the regions further north. They are, with few exceptions, not Coniferous. It will not be out of place here to enumerate a few of the commoner or more striking trees as they will show very clearly the difference between these forests and those of the North. By no means are all the families represented in the hammock trees given in the list nor all the genera in the families mentioned. Moraceae: *Morus* and two species of *Ficus*, one of which always and the other often starts life as an epiphyte, eventually in that case destroying the tree upon which it is located. Polygonaceae, represented by the Pigeon Plum, *Coccolobis laurifolia*. Allioniaceae, with a small tree, *Pisonia longifolia*, and a woody vine, *P. aculeata*. Euphorbiaceae, represented by *Drypetes* and *Gymnanthes*, fair sized trees. Anacardiaceae, represented by *Metopium*, a sumac reaching a height of 12 to 20 meters. Sapindaceae, with *Sapindus* and *Exothea*. Myrtaceae, with *Eugenia*, *Anamomis* and *Chytraculia*. Sapotaceae, with four or five genera, one species, *Sideroxylon mastichodendron*, attaining a height of

20 or more meters and a diameter of 60 to 100 cm. Verbenaceae, represented by *Citharexylon*, a small tree. Bignoniaceae, with the calabash, a species of *Crescentia*. Rubiaceae, with two or three arborescent species of *Guettarda*. The list might be increased much more. Perhaps the most important tree in many hammocks has been left until the last, *Quercus virginiana*, the Live-oak. With only a few exceptions all these trees are evergreen. To a large extent they possess shiny, often rather thick leaves, the prevailing shape being elliptical.

Many of these trees have low hanging branches and some, e.g. *Ficus aurea*, called locally on that account "wild banyan," send down roots from their branches which enter the ground and root there and form, as it were, secondary trunks. The trees with very smooth bark, especially those whose outer bark scales off or weathers away as powder, remain mostly free from epiphytes on their branches, but the others are sometimes so covered with mosses, ferns, orchids, bromeliads, etc., that their own foliage is quite hidden. In such a hammock the ground is covered with a profusion of ferns and slender shrubs, as well as a thick growth of small and large herbaceous plants. Some of the latter are vines that run up over any support they can find. Among the climbing plants are two or three species of *Vanilla*. A very disagreeable woody climber, which has already been mentioned, is *Pisonia aculeata*. The writer has seen specimens of this in a hammock near Homestead attaining at the base a thickness of over 15 cm. and a length over all of 30 meters or even more. With its festoons of two centimeter thick vines, covered with claw-like thorns, it makes progress through a hammock in which it is abundant anything but rapid or pleasant.

One of the most striking features is the startling abruptness of the transition from the pine woods to the hammock. Frequently the trees of the latter are of almost of as great size near the margin as at the center. This is not the case, however, in hammocks that are increasing in size. There is but a fringe, often not over three or four meters wide, of smaller shrubs and when this is traversed one is in the dense hammock. This sudden transition from a semixerophytic to a decidely humid formation has led many botanists to conclude, at first glance, that there must be marked soil differences to account for the difference in the vegetation. Yet, strange as this may seem, it is apparently not the case. The soil in the region about Miami is a more or less porous limestone rock, nearly solid in places but more often with numerous crevices and pits filled with sand. Sometimes the rock lies bare, but perhaps more often it is covered by a layer of sand several centimeters deep. Here and there occur peculiar well-like pits from 15 cm. to two meters in diameter and up to three or four meters in depth, the deeper ones containing water, at least at the bottom. These so-called pot holes are probably the result of the solvent action of water at a time when the ground was submerged. They are frequently lined by the most delicate ferns, e. g. species of Hymenophyllaceae. Except for a greater amount of humus in the soil due to the decay of the dense vegetation it supports, the soil in the hammocks appears the same as that in the pine woods.

How, then, can we account for these marked differences in vegetation? The soil is the same, except for the differences noted, and these are better explained as a *result* of the presence of the hammock than as the cause. Some hammocks seem not to be increasing in size, but the fact that some are spreading would show that it is not entirely a question of soil differences. The writer's observations led him to suppose that the genesis of a hammock is about as follows: Somewhere in the pine woods a few of the small shrubs or occasional small persimmon (*Diospyros virginiana*) or other broad leaved trees of which a few kinds are found also in the pine woods, form a somewhat sheltered place within which the air is somewhat moister. Here, owing to the increased shade, the soil does not dry out so much as where the sun is more direct. Other trees, favored by this increased moisture of soil and air, especially the live-oak, are thus enabled to get a start. Soon more trees and shrubs appear, the conditions becoming more favorable the more numerous and larger they become. The whole space underneath the trees grows up to underbrush. The denser the growth becomes and the larger the trees, the more humid is the air, while the dense shade protects the soil from drying out. Many of the plants that in the open pine forest are small shrubs become fair-sized trees when they encounter these more favorable conditions. Thus it is not necessary to suppose that all the hammock species

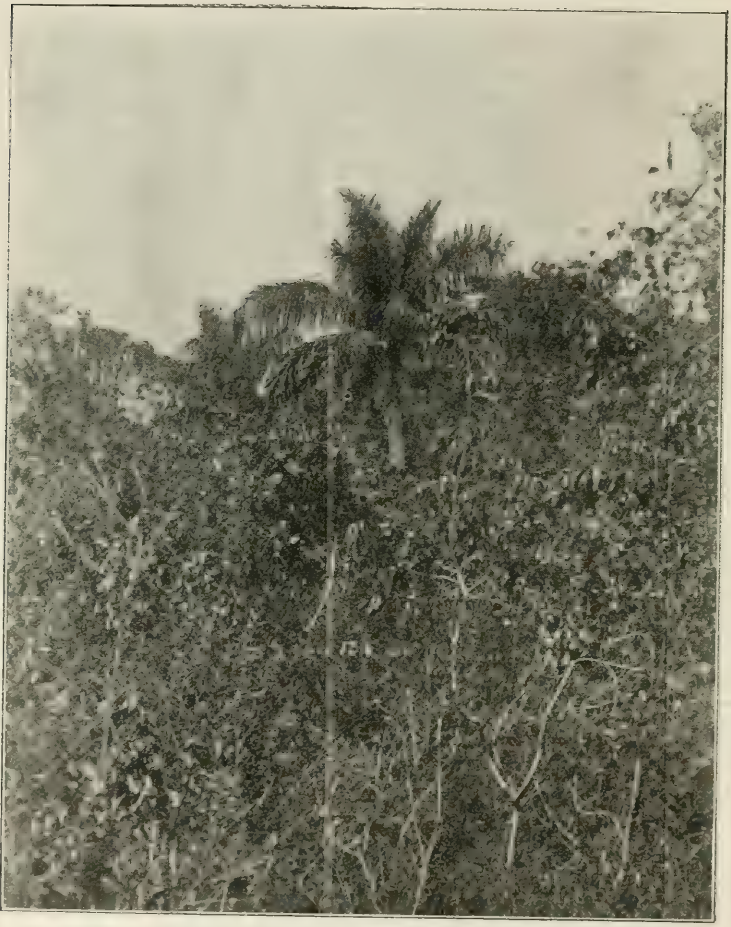

Fig. 1. The interior of a hammock, with the Royal Palm *Roystonia regia*.

must migrate from some distant hammock to take part in the formation of a new hammock. Examples of such plants that are small in the pine woods but form trees in the hammocks are a species of *Guettarda*, fruiting at a height of 30 to 60 cm. in the former situation and forming a tree six or more meters in height in the hammock, *Icacorea paniculata*, *Tetrazygia bicolor*, and many others. The denser the growth, the more humid the air and the moister the soil, so much more fully do these and other typical hammock plants reach their full development. Soon epiphytes begin to appear, other typical hammock plants come in and we have a typical hammock. This may gradually spread, the narrow margin of shrubs forming conditions in many respects similar to those in the first cluster of shrubs or small trees in which the hammock took its origin. That it is the slightly increased moisture and shade that favor the origin of a hammock as well, as its spread seems borne out by the fact that many hammocks have as the center from which they spread, as their base of operations as it were, some naturally moister spot, such as a depression in which water stands or lies near the surface and occupied by some trees that love such locations, e. g. *Anona glabra*, *Magnolia glauca*, *Diospyros virginiana*, etc. Thus along the margin of a stream the border of trees that occupy the moist banks furnishes the base from which the hammock can spread into the surrounding dry pine woods. It must be borne in mind, however, that the hammock proper is that portion occupying the land won away from the pine woods and not the moister belt of trees bordering the stream from which the hammock got its start. The typical hammocks are so dense that it is doubtful whether they ever have freezing temperature clear within them as far south as Miami. In the pine woods, on the contrary, frosts are fairly frequent and temperatures of 5 C. are not unknown. Thus it is that the hammocks may contain within them species typical of the tropics, e. g. *Swietenia mahagoni*, the mahogany, *Carica papaya*, the papaya, *Alvaradoa amorphoides*, *Sideroxylon mastichodendron*, etc., while the pine woods are far less tropical in their flora and the Everglades actually contain many northern plants

The Everglades are much misunderstood. To those not familiar with them the name probably conjures up a picture of a dense, almost impenetrable swamp, with large trees, covered with hanging "moss", slimy pools swarming with alligators and venemous snakes and air alive with deadly mosquitoes. This, however, is far from the truth. Perhaps the Everglades can be described best as low prairies, submerged for most of the year. They are free from trees except as noted below. Their level is from a few centimeters to as much as half a meter below that of the pine lands. The soil is frequently a sort of a marl, although vast areas have sandy and others muck soil. Not rarely does the limestone crop out as in the pine and hammock land. The vegetation consists largely of Monocotyledonous plants, chiefly sedges, grasses, rushes, Eriocaulaceae, etc. Orchids occur also in the parts not deeply submerged. The vegetation is not so strange to the botanists from the North as is that of the hammocks or even the pine woods. To be sure *Carex* will be missed but there will be found in its place many other sedges such as *Scleria*, *Rhynchospora*, *Dichromena* and all too many species of *Cyperus*. *Peltandra virginica* will remind

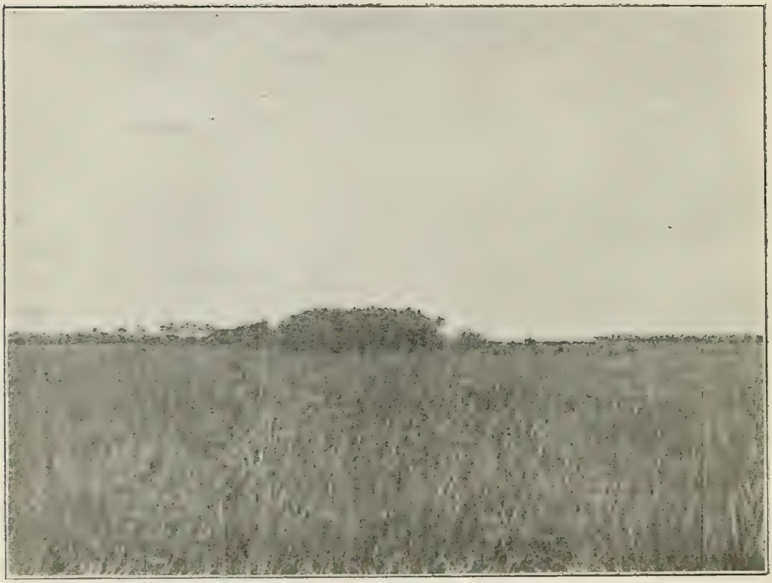

Fig. 2. A hammock in the Everglades. In the distance pine woods of the upland.

him of home while species of *Ludwiga*, *Utricularia*, etc., will also appear as old friends.

When the Everglades are submerged the danger from freezing is absent; indeed when the water is high even the adjoining pine lands are to some extent protected from frost. Usually, however, the winter is the season for low water so that it happens that very severe frosts strike the Everglades. Hence it is that strictly tropical forms are largely lacking.

Here and there where the land is a little elevated, so as not to be so subject to inundation, we find the so-called "islands" covered with a dense growth of trees. The smallest of these islands may not contain over four or five trees, semi-aquatic in nature, such as *Magnolia glauca*, *Anona glabra*, several species of *Salix*,etc. The larger of these islands may contain a portion that lies permanently above inundation and such portions are usually occupied by true hammocks, bordered, where occasional flooding takes place, by a margin of the trees just mentioned. Next to these, where the ground is submerged most of the time, begins the true glade formation. It is true that there are a few large islands which contain not only hammock but also pine woods. As one glances across the Everglades in some places but few of the islands can be seen, while in other places they are numerous and fairly close together. The ground is not perfectly level but at more or less frequent intervals are depressed water courses which usually remained filled with water even when most of the area is dry. In these swales the "sawgrass" *Cladium effusum*, abounds, often growing as tall as a man on horseback.

The water is clear and abounding in fish, and is, probably on this account, remarkably free from mosquitoes. It is only near the islands, where may be found pools where they may breed, that these pests are really bad.

These three types of plant formation (not using this word necessarily in its strict ecological signification), hammock, pine land and glade, stand in need of careful ecological investigations by precise methods. The writer has outlined conditions as they appear to an observer who has made no instrumental observations to confirm his theories. It is highly desirable that the following problems be studied carefully:

the relative humidity of hammock and pineland and its relation to the development of the hammocks; the temperature, especially the extremes, in hammock, pineland and glade; the influence of soil moisture, insolation, etc. It seems likely that, as has been demonstrated for some marshes in the North, the tops of the Everglade plants are really in a semi-xerophytic location, even when they are standing in water. This should be determined. To work out these and other kindred questions properly would require residence in the vicinity. The necessary observations would be extended over a period of several weeks, if not months. This paper is written in the hope that some botanist may take up the problem and carry it on to its solution. The writer intended to do this but his removal from Florida makes it impossible and he hopes that some one else may find it possible to spend the time necessary for these investigations. Doubtless he could make use of the buildings of the Subtropical Garden in his work.

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BOOKS AND CURRENT LITERATURE.

PHYTOGEOGRAPHY OF NORTH AMERICA.—Harshberger's monumental work, "A Phytogeographic Survey of North America," has recently appeared as the thirteenth volume of Engler and Drude's series "*Die Vegetation der Erde*." *

The volume comprises (a) a sketch of the history of botanical exploration and botanical institutions in America (45 pp.), (b) a description of the salient features of the geography and climatology of North America, with some statistics of the flora (77 pp.), (c) a literature list (47 pp.), (d) an outline of the geological history of the flora (77 pp), (e) a description of the "phytogeographic regions, formations and associations" of North America (359 pp.). The first two of these sections are inserted in accordance with the custom of some of the volumes of *Die Vegetation*, the first being quite as detailed as is necessary to the purpose of the volume, the second very cursory and well designed to orient the foreign reader of the following pages. The bibliography, for which the author does not claim completeness, is a very full one and forms an extremely useful feature of the book. The outline of the geological history of the flora takes up the thread at the commencement of the Cretaceous, the moment from which the history begins to throw strong light on the present assorting of the flora. The influences of the changes in the configuration of the continent during Cretaceous and Tertiary time and of the occurrence of the glacial period are treated in detail for the several phytogeographical regions. This section of the volume is well done, and to it belongs a large share of the interest of the book. We have had no comprehensive treatment of the phytogeography of North America, as interpreted by the geological history of the flora, for 30 years, a period during which geology and paleobotany have made great strides. The description of the vegetation of the continent is the core of the volume, being at once the part for which the author planned his preliminary studies and the part in which he approached his most difficult undertaking. He has made a digest of the descriptive literature which is available,—a most prodigious and thankless task,—to which he has added his own observations in several portions of the United States, Mexico and the West Indies. The phytogeographical subdivision of North America by Harshberger is the first that has been made by an American writer, and is, as we might expect, more detailed and more natural than the partitions made by Drude (*Atlas der Pflanzenverbreitung*, 1887) and by Engler (*Die Pflanzengeographische Gliederung Nordamerikas*, 1902), to mention only the best of the previous attempts. Harshberger's map of North America has been prepared so as to depict the floristic areas, but comes near to being an equally good representation of the regions of vegetation as well. This circumstance is partially inherent in the facts and partially an index of the extent to which floristics has been influenced by physiological plant geography in recent years. The map is not quite so detailed as its scale would have permitted it to be, in fact there are a number of minor particulars in which Engler's map is superior to it.

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*Harshberger, J. W. Phytogeographic Survey of North America. Die Vegetation der Erde Vol. 13. pp. 863, 32 figs., 18 pls., 1 map. Leipzig, Engelmann, 1911 ($13.00).

A work of this character and magnitude can be accomplished only by a heavy reliance on the observations of other men, not only entailing a dependence on their accuracy, but an equally important one on their ability to see the things that are most significant. Superadded to this is the necessity that the compiler see in each paper the features and facts that the author considered most important. The Survey has suffered in some respects from these difficulties, inherent in such a great undertaking, but it is nevertheless an extremely valuable volume, rising far above its errors of detail to give a delineation of the botanical features of our continent which will be very useful to American botanists, and, by virtue of its place in *Die Vegetation*, will stimulate European interest in our vegetation.

The editors of *Die Vegetation der Erde* should not escape without censure for having alloted the whole of North America to a single volume of their series. They have driven the author to the committing of a most pardonable and natural error in giving more extended treatment of the regions best know to him personally than their botanical features warrant. The Maritime Provinces and New England have 29 pages devoted to them, while the whole of the magnificent, diversified vegetation of Mexico receives only 30 pages. That this is not due merely to the redundancy of literature relating to the former region as compared with its scarcity for Mexico ,is shown by the covering of 18 pages with the description of the coastal plain region of New Jersey, Delaware and Maryland, whereas only 20 pages are given to the Great Plains and the same number to the Great Basin and its mountain ranges. Either the editors or the author must also answer for not having given more space to illustrative matter in dealing with a subject which invites liberal illustration and is so greatly illuminated by it. The volume contains a number of excellent illustrations of vegetation, but suffers greatly in this respect by comparison with the recent volumes on Africa. The whole of the West Indies, Central America and Mexico is illustrated by only ten cuts, the Great Plains by three and the Great Basin by not a single one.

The volumes of *Die Vegetation der Erde* by Pax, Willkomm and Graebner dealt with small areas, thoroughly known to the author. The volumes on Africa by Engler are the product of his own many years of interest in African vegetation, the cooperation of several of his colleagues and the combined attack upon its flora that has been made by the strong forces of the Berlin Botanical Garden. Americans have only to regret that this continent has been deemed worthy of so small a place in a series which began with such thorough treatment of small but characteristic areas in Europe. Every adverse criticism of any importance which can be made of Harshberger's work grows out of the immensity of his task, and we can only admire the zeal and enthusiasm with which he accepted the invitation of the editors to undertake the treatment of so large an area; at the same time that we prize his volume as a most valuable work, serving at once as the most complete picture of North American vegetation which we possess and as a back-ground for the future work of American plant geography and for the work of those to whom the facts of plant geography are in the nature of raw materials.—F. S.

NOTES AND COMMENT.

Prof. Douglas H. Campbell has just contributed to the American Nature Series (Henry Holt & Co.) one of the best of the scientifically popular books on the evolutionary history of the vegetable kingdom that has come to our notice. ''Plant Life and Evolution'' is essentially Prof. Campbell's earlier ''The Evolution of Plants'' brought down to date as respects mophological therories, together with a consideration of the factors in evolution and the origin of species, and some discussion of the bearing of the larger features of plant distrihution on phylogenetic history. The most noticeable feature of the book is its catholicity towards all the existing views on the operation of the evolutionary processes, and on the phylogeny of the larger groups of higher plants. This is doing no more than to reflect the current state of biological opinion on these matters, but we may well congratulate ourselves that the general public is being presented with reading matter of this timely and authoritative caracter.

The principal features of interest at the annual meeting of the Botanical Society of America in Washington will be the address of the retiring president, Dr. Erwin F. Smith, on the relation of the crown gall disease to cancer, and the symposium on ''Modern Aspects of Paleobotany,'' in which the participants will be Dr. F. H. Knowlton, Prof. John M. Coulter, Prof. E. C. Jeffrey and Dr. Arthur Hollick.

The results of the collective activity of the Central Committee for the Survey and Study of British Vegetation have been issued by the Cambridge University Press in a volume entitled ''Types of British Vegetation.'' The contributors are Tansley, Moss, Rankin, Cole and West.

Volume 14 Number 12

THE PLANT WORLD

A MAGAZINE OF GENERAL BOTANY

DECEMBER, 1911

PAPER ATMOMETERS FOR STUDIES IN EVAPORATION AND PLANT TRANSPIRATION

BURTON EDWARD LIVINGSTON

The porous-cup atmometer[*] and its light-absorbing modification[†] were devised to record the effects of the evaporating power of the air and the intensity of sunshine as these factors might influence the rate of water loss from ordinary leafy plants. The instruments, however, fail to simulate the essential structure of plant foliage in respect to the relation existing between the amount of exposed water surface and the volume of contained water. While the amount of contained water in leaves is very small, relative to the moist cell walls (internal and external) from which evaporation occurs, the volume of water in the porous-cup is very much greater, in proportion to the moist clay surface exposed. It thus comes about that the temperature lag of the cup is sometimes more pronounced than that of a leaf; as the air cools at sunset or is warmed at sunrise the large mass of water in the cup keeps the exposed surface warmer or cooler for a time, as the case may be. The coming and going of clouds sometimes brings out similar failure of the instruments quickly to respond to changes in the external temperature. A leaf, on the other hand, responds to many such changes almost instantly. Thus, for detailed analyses of conditions the instruments as hitherto constructed are sometimes inadequate, and the results may be misleading.

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[*] **Livingston, B. E.**—Operation of the Porous-Cup Atmometer, Plant World, **13**: 111-118, 1910. The literature of the instrument is there cited. Additional citations bearing upon the instrument and its use are the following:

Dickie, M. G.—Evaporation in a Bog Habitat, Ohio Naturalist, **10**: 17-23, 1909.

Dachnowski, A.—Physiologically Arid Habitats and Drouth Resistence in Plants. Bot. Gaz., **49**: 325-339, 1910.

Transeau, E. N.—A Simple Vaporimeter. Bot. Gaz., **49**: 459-460, 1910.

Brown, W. H.—Evaporation and Plant Habitats in Jamaica. Plant World, **13**: 268-272, 1910.

Livingston, B. E. A Study of the Relation Between Summer Evaporation Intensity and Centers of Plant Distribution in the United States. Plant World, **14** 205-222, 1911.

Livingston, B. E. and Brown, W. H.—Relation of the Daily March of Transpiration to Variations in the Water Content of Foliage Leaves. Bot. Gaz., in press.

Dachnowski, A.—The Vegetation of Cranberry Island (Ohio) and its Relations to the substratum, Temperature and Evaporation. Bot. Gaz., **52**: 1-33, 1911.

Fuller, E. G.—Evaporation and Plant Succession. Bot. Gaz. **52**: 193-208, 1911.

[†] **Livingston, B. E.**, Lignt Intensity and Transpiration. Bot. Gaz. **52**: 417-438, 1911.

Idem—A Radio-Atmometer for Comparing Light Intensities. Plant World, **14**: 96-99, 1911

In seeking a practical modification of the apparatus, by which this defect might be remedied, my attention was first drawn to the Piche atmometer *. This valuable device consists essentially (see Fig. 1) of a graduated glass tube, closed above and covered below with a circle of absorbent paper, the latter having a pin-hole in its center. The tube is filled with distilled water, the paper disk applied and affixed by an adequate clamp, and the whole inverted. The entire disk soon becomes wet, and evaporation therefrom draws water from the tube, air rising through the pin-hole to replace the water withdrawn. The central portion of the disk is covered above by the end of the reservoir-tube, below by a small plate which supports the paper.

This instrument possesses little temperature lag; a paper may be used which is thinner than many common leaves and holds but little water, and the lag-effect of the water mass above its central portion, and of the thin metal disk below, is negligible, so far as I have been able to detect. But the Piche atmometer has four characteristics which makes it unsuitable for detailed transpiration studies: (1) the hydrostatic pressure upon the paper is irregularly variable; the entrance of air through the pin-hole is exceedingly spasmodic, so that a considerable error is introduced into small readings. (2) It is practically impossible to place the evaporating portion at a distance from the graduated reservoir, an arrangement which is often desirable or necessary when the moist surface must be in close proximity

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*Piche, A.—Note sur L'atmismometre, Instrument Destinee a Measurer L'evaporation. Bul. Assoc. Sci. de France, **10**: 166-167, 1872. For other references see Livingston, Grace J., An Annotated Bibliography of Evaporation, Mo. Weather Rev., 1908-1909.

with the foliage of a plant. (3) The soft paper circle fails to maintain its horizontal position when openly exposed; slight air movement alters the exposition from time to time, and the wind often throws the instrument completely out of operation. The use of a thicker paper involves a larger amount of contained water. (4) The plane evaporating surface is unsuited to the purposesand needs of sunshine records with the radio-atmometer; the evaporating surface of the latter instrument must be placed so as to receive sunshine ever at the same angle throughout the day, and the only way to meet this condition with a disk is to mount it upon a heliostat, which is manifestly impracticable.

I have obviated the first two difficulties essentially by inverting the whole instrument, placing the reservoir below and the paper disk above. This is, in principle, the modification of the Piche Atmometer described by Cantoni. † The lower end of a burette (see Fig. 2) is attached by rubber tube to a vertical glass tube (about 6mm. in diameter with smooth end) which may be at any convenient distance. A second reservoir for filling the burette (usually a bottle with siphon and pinch-cock) is also attached, either by means of a T-tube or simply to a side opening. The burette is filled with water, the glass tube is lowered till water over-flows at its upper end, and the center of a disk of filter paper is firmly appressed to the latter. Maintaining some pressure with the finger upon the center of the paper, to prevent air entering the tube, the latter is now carefully raised until the paper is some distance (10 to 30 cm.) above the level to be taken as zero on the burette. The finger is then removed and the instrument is in operation. A suitable plate and clamp, similar to that used on the Piche tube, renders the paper less liable to be displaced. The water level in the burette should not be allowed to fall more than a few centimeters; the water seal where the paper is appressed will not bear high pressure. A freer movement of water is obtained if one or more little paper circles be placed upon the center of a large circle, over the end of the tube. The evaporating disk may be several centimeters in diameter; I find the smallest size of cut filters suitable for rather intense evaporation, for lower rates larger papers may be used. Care must be exercised that the evaporation rate never exceeds the possible rate of supply by lateral diffusion past the wall of the tube. When such is the case (the same consideration applies to the Piche instrument), the margin of the paper becomes dry and the readings have no value. Such an arrangement operates a day or two in the greenhouse without attention, but is highly unsuited to work in the open. It will be observed that this form of atmometer resembles the porous-cup form, excepting that the cup is replaced by the paper disk. For radio-atmometry with this device, the black cut filters now prepared by Schleicher and Schüll are admirable. In this form, which may be called the Cantoni-Piche atmometer, the spasmodic variation in hydrostatic pressure and the difficulty of separating the reservoir and scale from the evaporating surface have both been removed. A wire support for the edge of the soft paper circle obviates the troubles arising from air currents, but this,with the clamp, which is also necessary in the open, renders the device cumbersome and difficult of manipulation.

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†Cantoni, G.—Sulle Condizioni di Forma e di Esposizione pui Opportune per gli Evaporimetri. Rend. r. inst. Lomb., 12 (Ser. 2): 941-946, 1879. Abstract in Zeitscher. Oest Ges. Met., 16: 39-40, 1881.

The fourth objection mentioned above cannot readily be overcome so long as a disk is used for the evaporating surface, but is completely obviated by the cylindrical porous-cup. It was therefore highly desirable to combine the good points of the Cantoni-Piche apparatus with that of a cylindrical evaporating surface. This has at length been accomplished, through what may be termed the *paper cylinder atmometer*.

The evaporating surface is furnished by one of Schleicher and Schüll's extraction thimbles. These are made of pure filter paper, pressed into the form of a test tube, and may be obtained from dealers in chemical supplies. I have used the size 19 x 90 mm., S & S Extractions Hulsen No. 603. Originally, the thimble was merely inverted over the end of the filled glass tube and pressed firmly into place by means of the finger, in a manner quite paralell to that of placing the paper disk of the Cantoni-Piche form. This operation flattened the rounded end of the thimble, however, and proved unsatisfactory for other reasons. A better contact between paper and tube was attained by the construction of a special seat for the thimble, of metallic tin. While the latter might be made of glass the tin is more readily manipulated and its extremely slight solubility in distilled water renders it quite satisfactory. The seat is constructed as follows:

The rounded portion (less than 1 cm.) of the end of a paper thimble is cut off and the little paper cup thus obtained is supported, concave side uppermost, in a mass of sand, care being taken not to alter the original form of the thimble end. A piece of "block" tin tubing (about 6mm. outside diameter and 10 cm. or more in length) is placed and supported upright in the center of the little paper matrix thus prepared, and the latter is filled with molten tin. After cooling the casting is trimmed and smoothed with knife and file, the bore of the tube is reopened, and the seat is finished. Where a number of instruments are to be prepared, better procedures than the one above described may readily be devised; this one has proved satisfactory and can be followed in any laboratory.

The tin tube is now attached to the burette, in place of the glass of the Piche-Cantoni arrangement, a paper cylinder is passed down over the tin casting and carefully pressed into position, where it should fit snugly (see Fig. 3). With the finger pressing the paper firmly against the opening in the seat, water is now made to rise in the tube, expelling all air before it, until the closed end of the paper cylinder is thoroughly wetted, when the finger is removed. The instrument as thus set up, operates several days in the greenhouse; frequent filling of the burette should prevent the occurence of a pressure of more than a few centimeters of water column.

The instrument is completed and rendered stable enough for almost any sort of work by two additions, that of an arrangement to hold the cylinder more firmly in place and prevent the entrance of air, and that of a support at its lower free margin. My clamp was made as follows. A test tube is selected, into which the filter thimble will just fit, its closed end is cut off (by means of an emery wheel) and ground down till it forms a small,

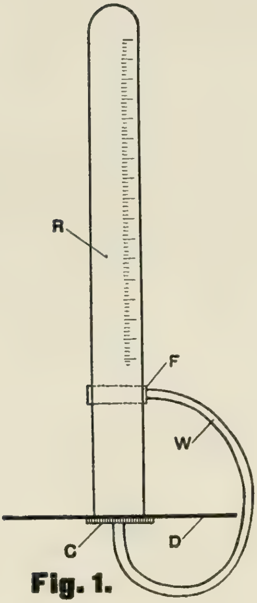

Fig. 1.

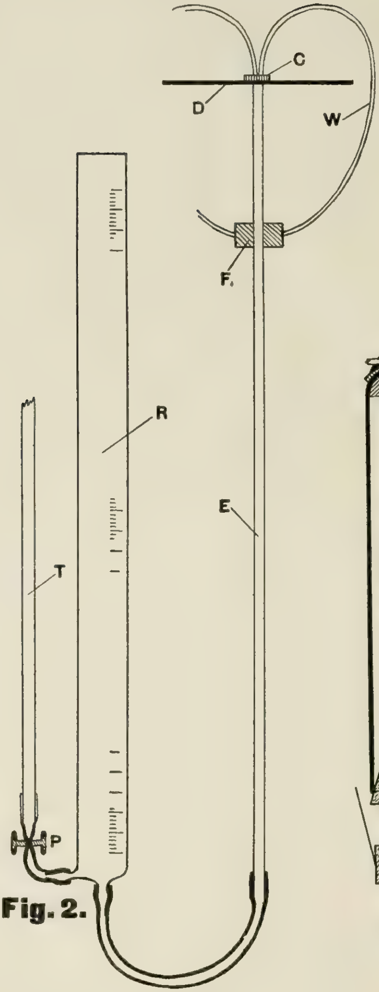

Fig. 2.

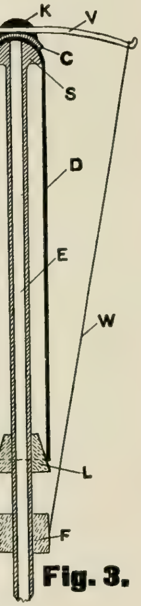

Fig. 3.

Fig. 1. Diagram of the Piche Atmometer. R, graduated glass reservoir; D, absorbent paper disk; F, metal clip about reservoir; W, metal spring; C, metal disk holding paper in place.

Fig. 2. Diagram of the Cantoni-Piche Atmometer. R, graduated glass reservoir (burette); T, Supply tube from higher reservoir, for filling burette; P, pinch cock; E., tube supplying the evaporating surface; D, absorbent paper disk; F, cork ring on tube E; W, metal spring; C, metal disk holding paper in place.

Fig. 3. Diagram showing mounting of the paper cylinder, the rest of the instrument as in Fig. 2. E, tin tube; D, Paper cylinder; L, cork wedges to hold lower edge of cylinder in place; S, tin seat; F, cork ring on tube E; V, metal spring, flexed by W, fine wire; K, cement holding V to C, concave glass cap, which presses upon closed end of cylinder, holding it in place.

concave shell (3 or 4 mm. in depth) which fits perfectly upon the rounded end of the paper cylinder. Across the center and on the convex surface of this little glass cap is cemented by its middle (De Khotinsky cement is excellent) a short piece of spring brass wire (5 or 6 cm. long) slightly turned upward at its ends. Two fine wires are affixed to the tin tube somewhat below the free edge of the paper cylinder and these terminate in loops to pass over the hooked ends of the springs just mentioned, when the glass cup is in place. The fine lateral wires must be of such length that the proper amount of pressure will be exerted upon the closed end of the paper cylinder. To place the clamp in position, the glass cap is carefully laid in position upon the top of the thimble and pressure is applied with the fingers to hold it and its cross-wire in place. The looped end of one lateral wire is now hooked over one end of the cross-wire. Then the opposite end of the latter is slightly flexed downward till the second lateral wire is brought into place upon its hook. The tension of the spring cross-wire thus distorted supplies the needed pressure, and the tube may now be moved about with little fear of air leakage.

To prevent wind from loosening the paper cylinder, pressing it against the tube on this side or the other, three or four tiny bits of paraffined cork are cemented to the latter to form little wedges upon which the free margin of the paper rests, or a deeply fluted cork stopper is properly placed upon the tube. These little cork projections do not close the annular opening between the tube and paper and yet furnish to the latter the needed support. Thus arranged, the paper cylinder atmometer may be safely exposed to the strong wind. Under very intense evaporation the thimble must be shortened, otherwise its free edge becomes dry.

Another method of affixing the paper cylinder to the tin seat, which has given very good service in the open and which possesses several advantages in the preparation, if not as many in operation, is the following. Common red sealing wax is melted in a suitable container and the closed end of paper cylinder is dipped therein, so as to form a heavy, very slightly elastic cap of sealing wax a centimeter in height.

The wax does not penetrate the paper but adheres firmly to its outer surface. In setting up the instrument, the cylinder is lowered over the seat till it comes into position, the water reservoir is raised till water drips from the lower edge of the paper, and the wax cup is pressed firmly against the seat while the reservoir is lowered. With proper care the reinforced cylinder tip grips the tin seat with sufficient force to maintain itself in position. The base of the cylinder should be supported as above.

In the paper cylinder atmometer, the evaporation takes place almost entirely from the exterior of the cylindrical surface. At the same time an ample air space separates the moist paper from the water-filled metal tube, and very rapid adjustment to changes in the surrounding temperature is allowed. For some purposes it may be desirable completely to close the annular opening below, as by a thin cork ring. The volume of water held, while considerably greater (proportionately to the active surface exposed) than in the thinner paper disk forms, is not large. These thimbles hold water to an amount about equalling 70 per cent. of their dry weight, this being less than the amount held in the foliage of many thin-leaved plants. The surface may be blacked by the use of washed lamp-black and water, as on the porous-clay cup, for the measurement of light effects, and the whole cylinder may be placed in any position, at any angle, with perfect safety. It has been found that the process of washing sometimes results in a more or less pronounced agglutination of the lamp-black into larger granules, (at least in the case of certain varieties of this material) and a substitute therefor has been found in the finely divided manganese dioxid which results from the reduction of potassium permanganate by boiling its solution with a little cane sugar. The precipitate is washed and decanted several times and then used in the same manner as lamp-black.

In the perfecting and testing of the paper cylinder atmometer I have been assisted by Mr. Lon A. Hawkins, to whose ingenuity the details of the metal seat are especially due; also by Prof. J. S. Caldwell, to whose able co-operation at the Desert Laboratory during the summer just passed are due the working out of the sealing-wax cap and the manganese dioxid coating.

It needs also to be stated here that the new atmometer now described—and indeed the porous cup forms as well are to be largely attributed to financial aid from The Department of Botanical Research of the Carnagie Institution of Washington.

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ESTABLISHMENT BEHAVIOR OF THE PALO VERDE.

FORREST SHREVE

One of the most striking characteristics of the deserts of southern Arizona is the diversified assemblage of "vegetation forms" or "life forms" which they exhibit. These fall sharply into two classes,—the succulents and the sclerophylls, —the former of which is represented by fewer species than the latter but is of quite as great importance in determining the physiognomy of the vegetation. Among the succulents may be distinguished the leafless stem-succulent cacti, greatly diversified in size and form, the leaf-succulent *Agave*, the leafy stem-succulent *Yucca* and *Dasylirion*, and the root-succulent *Tumamoca*. Among the sclerophylls there are less striking differences of gross form, but equally important distinctions in character of foliage and seasonal habits. As examples may be noted *Covillea*, with small evergreen leaves, *Celtis pallida*, with broad, evergreen leaves, *Prosopis* and *Acacia*, with deciduous dissected leaves, *Jatropha cardiophylla* with broad deciduous leaves, *Fouquieria*, with ephemeral broad, thin leaves, *Parkinsonia*, with minute deciduous leaves and chlorophyll-bearing bark, and *Ephedra*, with leafless chlorophyll-bearing stems.

Spalding has shown * for this region that a number of the characteristic types are limited to certain topographic sites, and that many occur abundantly in certain situations and only sparingly in others. However, on the higher mesas, the basaltic hills and the foothills of the larger mountain ranges may be found a relatively dense vegetation in which occur examples of nearly all, if not all, of the types which I have mentioned, growing intermingled under identical environmental conditions. The larger differences of soil texture and topographic site determine the flora of a given hectre of ground in such situations as these, but the relative abundance of this or that type or species of plant is not, I wish to maintain, so much a matter of physical conditions as they affect the adult plants, but rather an outcome of the vicissitudes of germination and establishment for the species of the flora of that area. After the larger features of the habitat have determined its flora, I am convinced that the actual make up of the vegetation, the relative abundance of the different types or species, and even,to a large extent, the density of the stand itself are products of the conditions which control germination and the activities of the seedling during its first twelve months. This is indicated by the extreme irregularity of admixture of vegetation types in small areas. The work of Cannon † has shown that great diversity of root habits exists among plants of the different types, which may have much to do with enabling a mixed population to survive on an area where a uniform population of the same number of individuals could not do so, owing to the fact that the different types secure their supplies of soil water either at different levels of the soil or at different seasons of the year. Serving merely as an extreme case of the irregularity of the allotment of desert plants are the not infrequent dense colonies of the same species, near which, and under identical conditions, may be colonies of other species. These cases are nearly confined to the cacti, however, which obtain their annual store of water during the summer rains and do not therefore invalidate the explanation of the usual diversity of stand which is afforded by the work of Cannon. These pure stands must also have their explanation in the chances of seeding, germination and establishment (or of vegetative multiplication) rather than in any physical differences of habitat.

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*Spalding, V M.—Distribution and Movements of Desert Plants Pub Carn Inst ,1909.

I am still further convinced that the chances of germination have a very important part in determining the character and density of desert vegetation, by the extreme slowness with which a piece of cleared desert becomes repopulated. Here is no question of the clearing having made the conditions for repopulation any less favorable than they are at any unoccupied spot in a virgin stand of desert plants. For example, there has come under my notice a block of ground within the city limits of Tucson, which is occupied by a stand of *Covillea* of the average density, through which there formerly ran three roadways. Ten years ago the block was fenced off and has not been used as a highway since. The roads had never been worked, but were simply made by the clearing of the ground and the wear of wheels. They are still conspicuously visible, and in them have not grown any young plants of *Covillea*.

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†Cannon, W. A.—The Root Habits of Desert Plants. Pub. Carn Inst., No. 131 1911.

The rate at which new individuals are added to natural stands of desert plants is also extremely slow in very many species. In the spring of 1906 Prof. V. M. Spalding surveyed and carefully charted an area near the Desert Laboratory on which there were growing, along with other plants, some 72 individuals of *Encelia farinosa*. In the spring of 1910 I went over this area and located each of the 72 plants and searched carefully for new individuals, finding only one, which died in the following month.

My interest in these phenomena led me to inaugurate work looking to the determination of: (a) the character of germination and seeding in different types of desert plants; (b) the nature of the vicissitudes which control germination and establishment, (c) the possible differences of establishment rate in different types of desert perennials. The first two of these objects are designed to secure knowledge as to the importance of the early ontogeny of the perennial types in determing their local distribution and in contributing to the characteristic complexity and openness of desert vegetation. The third of the objects is looking not only to the phenomena which may be operative in changing the character of the desert vegetation, but toward a possibility that secular changes of climate are rendering the conditions less suited to some of the desert plant types and more suited for others. I have undertaken two lines of work as sources of evidence on these problems: statistical work on adult populations and observational work on the actual occurences of germination and seedling mortality on a limited area. My work on this area has been confined to six common types, four of cacti and two of sclerophyllous trees. In addition to determining their germination behavior I have secured continuous records of the atmospheric evaporation rate and the moisture of the soil at depths of 3, 15 and 30 cm.

In a previous paper * I have reported on statistical work with the Giant Cactus, which went to show that it is not maintaining itself at its former rate of establishment. I have since endeavored to get similar statistics for the Palo Verde (*Parkinsonia microphylla*), which is a Leguminous tree, with chlorophyll-bearing bark and very small leaves, which are borne only in the rainy seasons of late winter and midsummer. In the stems of Palo Verde very narrow rings of growth are visible. By polishing and varnishing sections of trunks it is possible to count these rings by the aid of a hand glass. By counting the rings along several radii, and by recounting each section after I had recorded and forgotten how many rings it had, I was able to determine the number with no errors in my extreme differences of count of more than 10%. The fact that Palo Verde has two periods of foliation in the year made it seem probable that it might have two periods of growth in trunk diameter, although I had noted that its shoots made no growth of elongation in the late winter rainy season. In order to determine whether the rings of the trunk are annual or semi-annual I made a careful measurement of some thirty stem diameters on six individuals in two localities. The places at which the measurements were first made were marked by touches of paint, which proved to do the stems no injury. The measurements were made with micrometer calipers, reading to .1 mm. The result was that no growth was detected during the late winter period of foliation, showing the rings to be annual. In order to secure a curve of growth rate I cut 22 trees of different diameters and counted their rings. I then secured trunk diameters of a population of 146 treees on the north slope of Tumamoc Hill, over the same area on which I made one of my determinations of establishment rate in the Giant Cactus. The trees were measured with metal calipers such as are used in lathe work. The fact that the Palo Verde branches close to the ground made it necessary to measure the trunk diameter at the surface of the ground, and in some of the largest trees even to dig below the surface. Whenever the trunk was elliptical or irregular in section I averaged its greatest and least diameters. I then converted the set of diameter measurements into ages, by use of the curve of growth rate, and secured the following groupings of the number of individuals that became established during the periods indicated.

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*Shreve, Forrest—The Rate of Establishment of the Giant Cactus, Plant World, 13, 235-240, 1910.

PERIOD.	NUMBER OF TREES.
1490-1520	1
1520-1550	4
1550-1580	4
1580-1615	7
1615-1640	11
1640-1670	12
1670-1710	11
1710-1760	18
1760-1810	13
1810-1840	17
1840-1860	21
1860-1885	17
1885-1910	10

It is manifest from the antiquity of this population that I have no warrant for considering the above figures as any indication of the rate of establishment. Scores of individuals must have germinated, grown to considerable size and perished on this area since 1490. The figures merely indicate the age of the surviving individuals. However, the number of survivors from the 1840-1860 period to 1910 has steadily fallen, so that this portion of the curve, at least, is free from the error of having been seriously reduced by death of adult trees. How much I have to reckon with human interference I am unable to say, but such interference would at least be directed chiefly to the taking out of the largest trees for firewood, and might account in part for the low number of survivors of the greater ages, but would scarcely affect the individuals of the last three periods. I am inclined, then, to consider the figures just given as showing nothing with regard to a rise or fall of the establishment rate from 1490 to 1840, since the rise in number of individuals during that period merely indicates a shortening of the period over which various causes of death might overtake the trees. The fall in number of survivors in the last three periods, however, is not influenced by this error, or rather if the error is effective it has merely served to make the fall in that part of the curve less steep. The figures of the last three periods indicate, then, that there has been a fall in the rate of establishment during the last 60 years. That this fall lies over the same period in which I found a decrease in the establishment rate of the Giant Cactus indicates, tentatively, that whatever secular changes of climate may be taking place are affecting the largest of the succulents and the largest of the sclerophyllous trees in the same manner.

My detailed observations of the present rate of germination and seedling mortality have been made over an area of 640 sq. m., lying within the area over which the above mentioned census was taken. My method has merely been to go over the area carefully every few days at the time of the first summer rains, and to drive a numbered stake near each seedling. No germinations take place at any other time of the year. At periods of every two or three weeks during the year I go over the area and remove the stakes from all seedlings that have died since the last visit. The summer of 1910 was a very favorable one for Palo Verde germinations, and the total number was 542, over an area on which there are only eight adult trees living at the present time. Without giving the detailed record of the annual march of soil moisture and evaporation conditions, which I hope to do latter in a more detailed treatment of this entire matter, I will merely refer the number of deaths in the seedling crop of 1910 to the somewhat unique seasons of southern Arizona in the following table.

SEASON	NUMBER OF DEATHS	NUMBER OF SURVIVORS
Humid Mid-Summer, 1910	43	499
Arid After-Summer, 1910	157	342
Winter, 1910-11	74	268
Arid Fore-Summer, 1911	146	122
Humid Mid-Summer, 1911	60	62

The arid after-summer and the arid fore-summer are found to give rise to the greatest number of deaths, while the winter season and the humid mid-summer season give rise to a lesser number. The 62 seedlings surviving at the end of sixteen months are 11% of the original number of germinations. What the fate of these survivors will be may be inferred from the results of an examination which I made of all the dead seedlings which occupied my observational area when I began work on it in May, 1910. These represented, presumably, the deaths of the preceding 12 to 18 months, being 160 in number. After a prolonged soaking in glycerine and alcohol the seedlings were sectioned and their ages determined, with results as follows:

Age in years	1	2	3	4	5	6	7	8	9	10
Number	105	32	20	1	0	0	1	0	0	1

These figures indicate, as would be anticipated, that the greatest mortality occurs in the first year, that it continues at a rate which is high relatively to the number of survivors through the second and third years, and falls thereafter to a rate which is very low. The number of survivors at the end of the third year is probably never more than 3% of the number of germinations, and must often be none at all.

I have noticed that the severely arid conditions of the fore-summer cause the death of a great many twigs on Palo Verdes that must be from 10 to 20 years old, and on all sizes larger than that. The death of these twigs of course serves to cut down the water requirements of the plant and must operate in the direction of saving the remaining portion of the plant at a time of extreme transpiration and very dry soil. It is, in effect, analagous to the leaf-fall of the decidious trees in the dry months of monsoon climates, and is more crudely analagous to the contraction of volume under severe transpiration that is exhibited by the larger cacti. When a Palo Verde seedling becomes large enough to withstand the loss of some of its branches in the most critical portion of the year, its life is safe from all but droughts of the most extreme severity. When this age is attained, and it must be a variable one, the death rate falls to an extremely low figure. I have had a great many thousands of Palo Verdes come under my observation within a radius of 75 miles of Tucson, and have seen only two dead trees of full size.

I have found that the shade of adult trees and other large plants does not materially lessen the death rate, for the conditions of soil and atmospheric aridity are just as pronounced on the north side of trees and shrubs during the arid fore-summer as they are in other situations. I have not found that there is any importance in the number of seedlings occupying the same spot, as respects their chances of survival. There are several cases among the seedlings of 1910 in which two and three individuals growing as close together as possible have all survived to date, and on a single square metre with a population of nine seedlings the percentage of survival has been much higher than on the area as a whole. These considerations, together with the seasonal fluctuation in death rate, lead me to conclude that the "vicissitudes" and "chances" which determine the survival of Palo Verde seedlings are almost wholly physical, as distinguished from the so-called biological conditions, which is to say the physical conditions which are initiated by associated plants. By far the most important of the physical conditions are those which have to do with the maintenance of the transpiration-absorption balance of the seedlings.

The Desert Laboratory,
Tucson.

THE COMMERCIAL RAISING OF SEEDS

A. J. PIETERS

The personal experience of the writer has been confined to the raising of vegetable and sweet pea seed, but the fundamental problems are much the same in all kinds of seed raising, differing more in details than in the nature of the problems. In general, these may be grouped under two heads, the growing of the seeds, "making the crop," and the selling of them. The latter is perhaps the most difficult, and the root of probably nine-tenths of the trouble of the honest seedsman is to be found in the matter of price.

There is no inherent difficulty in raising good seeds, but it is impossible to raise them for the same price as poor seeds can be raised. The keenness of competition and the tendency of many dealers to buy where they can buy the cheapest has a depressing effect on the quality. The fact that the quality of vegetable seeds is not what it should be is the fault of the retail dealer. There is a good margin of profit in the retailing of seeds, and there is no reason why the retailer should not pay a fair price for his seed. If instead of paying the lowest possible price for a pound of lettuce seed he paid five cents a pound more he could get the best seed that is produced. If this seed is sold by the packet 100 of them will be filled from this pound, making the increased cost of the seed to him, all other items of cost remaining the same, 1-20th of a cent per packet. If the seed is sold in ounces and fractions, as is usual in the market garden trade, the added cost will be about 1-3 of a cent per ounce. These examples will serve to show that there is no excuse for the practice of many dealers who place their orders with a grower who will contract at the lowest price, rather than with one of the best growers.

This is the real problem of the grower. While experience and a good knowledge of horticulture are necessary to raise good seeds, there is nothing about this that could not be undertaken by most good gardners. In the growing of crops there are always local problems to be solved, soil and water conditions and labor, but these matters are incidental to all lines of agriculture. The special problem of the seed grower is keeping his stocks true. The types of our vegetables and sweet peas are not as a rule well fixed. This is due to the fact that there is no uniform method of describing new varieties, and but little effort is made to describe them at all. Many of the older sorts are pretty well fixed as to their main features, but the leading seedsmen are not agreed as to the details of the type. For instance, some claim that "New York" lettuce should have a pointed head and others claim that the head should be spherical. Some sell white seeded "Tennis Ball" lettuce and "Boston Market" for the same thing, while others point to certain differences in shade of color and firmness of the head and claim that they are distinct.

This lack of definiteness makes it difficult for the grower. He may have what he and some of the trade consider a good stock of a variety and find that another dealer does not consider the variety true to name. The writer some two years ago bought stock seed of a new variety of sweet peas form one of the best dealers and specialists in sweet peas. From this he grew a crop of seed and sold some to another dealer. In the course of time a complaint was received to the effect that the seed was not true to name. The whole trouble was that the two dealers did not agree as to the type of this variety. It is important that the grower should have clearly in mind what type he is going to grow. With this type in mind he makes his selections in accordance with the system he follows. As a rule those growers who do any selection at all confine this to a general selection of the best plants in the field. There is perhaps no pedigree work done at all. This requires too much time and expense, but the best growers follow a system of double selection. Each year they stake several plants as nearly perfect as they can find. The small quantity of seed produced by these plants is sown in a separate block, and from this block the general seed stock for the following season is taken. By this system no stocks will ever become absolutely pure, but only a small number of the "rogues" will appear every year. These are cut out before they bloom in case of the vegetable seeds, and as soon as the flowers are out in case of the sweet pea seeds.

Financially the pressure is in the direction of placing new varieties on the market or of raising the standard sorts at as low a cost as possible. The better growers do a certain amount of selection, but there is little effort to produce pedigree stock of the better sorts. The standard of the vegetable seeds sold by American dealers is much lower than it should be, but the remedy is in the hands of the dealer and not the grower. The latter must grow what his trade demands and at a price the trade is willing to pay. There are, of course, dealers who will pay a fair price for good seed, but this trade is rather limited, and any grower catering exclusively to it would do a very small business indeed. For the student of plant variation there is no better place than a large seed farm. The number of individuals is large, running into the hundreds of thousands for each variety. Sports are constantly appearing, and the fields afford unlimited opportunity for crossing.

University of Michigan.

BOOKS AND CURRENT LITERATURE.

THE DUNES OF NEW ZEALAND.—Cockayne has recently made a second valuable contribution to the literature relating to sand dunes and their reclamation.* His previous report, published in 1909, and reviewed in this journal for June 1910, presented the partial results of a scientific survey of the New Zealand sand dunes, made in the austral summer of 1908-09, under the direction of the Minister of Lands. It was confined to a consideration of the nature and the flora of the dunes of western Wellington, but the present paper covers those of the whole New Zealand biological area, and a second part is added which treats with great thoroughness the subject of their reclamation.

The dune areas of the North Island comprise 290,000 acres, that of the South Island 24,000 acres. They are for the most part situated on the coasts, but some of smaller extent in the interior. It is evident that the proper management of this large extent of territory is a matter of no small importance. In Europe the prime object of dune reclamation has been the preservation of the coast lines, but in New Zealand it is the protection of adjacent fertile lands, as well as the utilization, as far as possible, of the dunes themselves.

It is believed that before the entrance of civilized man upon the scene, nature herself had made the dunes stationary by clothing them with a protective indigenous vegetation. The number of plant species now growing on the dunes is 147, of which 82 are endemic and 43 Australian. Several of these native species are excellent sand binders or sand collectors. The author gives full descriptions of these, pointing out the special adaption which they possess for these purposes. The most efficient is *Spinifex hirsutus*, a rapidly growing perennial grass, having numerous stout, branching rhizomes of great length. Its method of seed dissemination is remarkably adapted to its habitat. It is dioecious, and has a globose female inflorescence, often a foot in diameter, composed of radiating spines some five inches long, at the base of each of which there is a one-flowered spikelet. Borne by the strong breezes these balls go bounding over the sand, ultimately breaking up and scattering their seeds far from the parent plants.

Since the settlement of the country the native covering has been largely destroyed by fires, grazing and cultivation, and the result has been that the dunes have become active, and are occasioning great damage, and threatening more. Even slight wounds in the surface, such for instance as might be made by a sheep rubbing its tick infested back, are liable to be scooped out and enlarged by the powerful winds, until eventually the whole hill is set in motion.

A few attempts have been made at reclamation, and in some cases a limited success has been achieved, but no comprehensive, intelligently directed scheme has been adopted. Plantings made in ignorance of the conditions of the problem have been ineffectual, and some injurious, for plants may create as well as restrain dunes. Much of the report is devoted to a statement of the principles and practices which must be observed for successful reclamation.

In New Zealand, as elsewhere, afforestation must be regarded as the ultimate solution of dune reclamation, but under the conditions there existing this can be accomplished only as the climax of a series of preliminary plantings. The author recommends beginning with Marram Grass (*Ammophila arenaria*), to be succeeded by the California Tree Lupine (*Lupinus arboreus*), and then by some of the native shrubs, and at last, under their shelter, by trees. Of these the most esteemed are the two Monterey conifers *Cupressus macrocarpus* and *Pinus radiata*, and *Pinus muricata*. An extended annotated list of plants worthy of trial is given, for it is felt that wide experimentation is needed to determine the species best adapted to varying conditions.

A curious instance of the inappropriateness of a popular name may be noticed. In the United States the European *Carduus arvensis* bears the misleading name of Canada Thistle; but according to this report in New Zealand it is called California Thistle, which is even more undeserved, since California is one of the few states of the Union in which this weed has not yet made its appearance.—S. B. PARISH.

NOTES AND COMMENT

The investigations of the Agricultural Department into the feasibility of utilising various crop wastes in the manufacture of paper have been recently summed up by Charles J. Brand in a Circular of the Bureau of Plant Industry (No. 82), which is not only interesting as respects reading matter but is an effective demonstration of the products that have resulted from this experimental work. The five sheets of paper which form the circular are made respectively from cornstalks and cotton hulls, broom corn stalks, rice straw and spruce wood, broom corn stalks and popular wood and from cornstalks. The quality of all these papers is very good, for, as Brand says, it has been possible to produce good paper from crop wastes, but it has not been possible to produce it at a cost lower than the present cost of other paper making materials. Cornstalks are one of the largest agricultural wastes and are one of the poorest paper-making materials tried. Broom corn produces a longer fibre than Indian corn, but is not grown in very large quantities. Rice straw and the bagasse from sugar cane both make good grades of paper, and they have the practical advantage that they are by-products of centralised agricultural industries. In all these cases it is possible to extract the soluble constituents from the waste, which are rich in protein and sugar, and will serve to lessen the cost of the paper made from them. The author states that the crop waste papers will be suitable for books, writing paper, etc , pointing out the features in which wood pulp paper is superior to any other for newspaper stock. The well-known rapid exhaustion of the supplies of spruce and other woods suitable for pulp making will, however, soon give an economic importance to the crop wastes as sources of all grades of paper. This little circular gives a cheerful tone to the prospects for the conservation of the Sunday Edition.

In a recent bulletin of the New York Botanical Garden Dr. Frank D. Kern has published "A Biologic and Taxonomic Study of the Genus Gymnosporangium." Dr. Kern has made the usual taxonomic study, in connection with which, as his title indicates, he has carried out several lines of investigation which give his published results far wider interest than is usually possessed by the monograph of a genus. He has made over 200 indoor cultures with a view to confirming and extending our knowledge of the life cycles. He has made a detailed study of the distribution of the species of Gymnosporangium and of the known host plants of its two stages, concluding that the presence of suitable hosts will assure the presence of the fungus, without regard to the environmental factors that are commonly concerned in the occurrence or absence of plants. A complete understanding of the genesis of the present distributional relations of Gymnosporangium cannot be had without further knowledge of the geological history of the movements of the host genera. Evidence is brought forward to show that there is a correlation between the suppression of uredospores in Gymnosporangium and the performance of the characteristic functions of uredospores by the aecidia and teleutospores. A discussion is also given of the pathological effects, economic importance and control of the genus.

Dr. F. L. Stevens, of the North Carolina Agricultural College, who has recently been appointed Dean of the College of Agriculture of the University of Porto Rico, is making plans for the establishment in Porto Rico of a research laboratory for botany and zoology. Of the several attempts which have been made in the United States to establish permanent tropical botanical laboratories in this hemisphere, this is the first that has looked to a location which is under the American flag. It is doubtful if this somewhat sentimental consideration will offset the much more advantageous natural conditions which characterise other localities in contrast with Porto Rico. However, such a station, maintained in connection with the University of Porto Rico, will have great usefulness, especially in researches relating to tropical agriculture.

Various bulletins of the Bureau of Plant Industry bearing date of 1911 are well worth the attention of botanists. Natural Vegetation as an Indicator of the Capabilities of the Land for Crop Production in the Great Plains Area, by H. L. Shantz (Bul. No. 201), brings out the capital fact that in the area under investigation (eastern Colorado) the general conditions of soil and climate, whether favorable or unfavorable to crop production, are indicated by the character of the native plant cover. Thus, for example, the land which bears a pure short-grass cover was found to be supplied with water only in the surface foot or two of soil and for a brief period during spring and early summer, while land with a uniform cover of tall grass was found to be supplied with water to a much greater depth and to offer conditions favorable to plant growth during a much longer season. Areas of greatest agricultural value, one year with another, are those marked by the presence of wire-grass vegetation. Bunch grass land is best for crops during very dry years. Short-grass land (grama-buffalo-grass association) produces more than any other type during wet years, but fails in time of drouth. These are but examples of the various correlations between the natural plant cover and the crop-producing capabilities of land in the areas studied, as they are presented by the author. The careful account of plant association, added to determinations of physical conditions, especially with soil moisture and run-off are of much interest to the student of ecology and also indicate something of the great value of such an investigation to the intending settler.—V. M. S.

The eruption of Taal volcano on an island of the same name in the vicinity of Manila, which occurred on the thirtieth of last January, affords botanists an opportunity similar to that offered by Kraktoa for studying the rehabilitation of an area over which vegetation has been destroyed as the result of volcanic action. The accessibility of the island renders it possible to maintain almost continuous observations, and the position of the volcano in the midst of a lake suggests problems of special interest.—V. M. S.

No more tangible evidence of the progress and practical character of the educational work going on in the Philippine Islands can come to us than is embodied in ''The Philippine Agriculturist and Forester.'' This is a monthly magazine started in January, 1911, and published by the students of the College of Agriculture at Los Banos. Its articles have the familiar flavor of our own agricultural bulletins, with an added dash of interest in rubber, fibre plants and tropical fruits, while the names of the authors would indicate that practically all of its contributions are from the native student body of the College. Much of the credit for the good work which this indicates must go to Dr. E. B. Copeland, the Dean of the Philippine College of Agriculture.

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